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THE INSTITUTE OF PETROLEUM

AN Ordinary General Meeting of the Institute of Petroleum was held at 26 Portland Place, London, W.1, on 2 January 1957, the Chair being taken by The Rt. Hon. Lord Geddes, President of the Institute.

The General Secretary read the minutes of the previous meeting, which were confirmed and signed as a correct record. He also announced the names of members elected since the previous meeting.

The Chairman, introducing the authors of the papers to be presented, said: This meeting is devoted to a symposium on staff training, and the three papers have been written from three complementary aspects, namely, the need for training; the contribution that formal company training makes to meeting those needs; and lastly, the techniques used for training.

T. L. Stephens, the author of the first paper, has had considerable engineering experience, first with the BPH and DMI companies, and later with the Anglo-Iranian Oil Company as head of the engineering department of Abadan Technical Institute. He was afterwards responsible for training at the Abadan refinery, and for the last five years has been responsible for industrial training in the BP organization.

R. S. Butler, the second author, was a member of the research staff of the National Institute of Industrial Psychology from 1948 to 1950, and during that period undertook research in the effectiveness of joint consultation. In 1950 he joined the Esso organization as supervisor of training at Fawley refinery, and since 1954 has been manager of the training department at the head office of the Esso Petroleum Company Ltd.

The third paper is by A. I. S. Debenham, who first joined the Shell Petroleum Company in 1937. He then joined the Shell Petroleum Corporation in the U.S.A., and after six years in the R.A.F. during the war, he returned to the Shell Petroleum Company on the equipment side of the Education Department. After further experience on the supply side of the company's operations he joined the Industrial Relations Department on supervisory training in 1950. Since that time he has taken an active interest in supervisory and management training techniques.

SYMPOSIUM ON STAFF TRAINING

RECOGNITION OF THE NEED FOR TRAINING*

By T. L. STEPHENS†

INTRODUCTION

OUR attention is constantly being drawn to the fact that oil is playing an increasingly important part in the world fuel position, and that the industry as a whole is growing steadily and will, as far as can be seen, continue to do so for some years to come.

This numerical expansion of the industry is accompanied by growing complexity in the techniques of the oil business, as well as in the field of oil politics and human relations.

Whatever progress is made in scientific method and technique, this expansion and growth is possible only if we have people within the industry with vision, who are resourceful, and who are capable of dealing with the more complex situations with which they will be faced.

The oil industry is worldwide and is truly international, with almost every nation participating in its operations, and there is the one common interest, that of being in oil.

With full employment in the industrial world there is a shortage of skilled manpower in every field of operations from the well-head to the kerbside pump, and with the expansion with which we are at present faced, we must make the utmost use of our available manpower and also provide for the future by carefully planned training.

This need for training has never been greater, and if we are to make the most of our available manpower, then we must clearly recognize training need. This paper attempts to state what the need is and how it should be recognized.

DEFINITION OF THE NEED FOR TRAINING

The overall definition of the training need of an individual in any environment is in itself simple. First we have the individual and we can measure, or find out, what he already knows and can do. Secondly, we can state clearly what he must know to be able to do the job for which he is being trained. Between these two points there is a gap, and the training need is that which bridges this gap.

* MS received 28 November 1956.

† The British Petroleum Co. Ltd.

It is then necessary to determine what training methods are required and what time is needed, so that the individual can be trained and become, it is hoped, competent to do the job.

Let us look at this more analytically. First of all the individual selected; he is the starting point, and his intelligence can be assessed by some accepted educational standard. Secondly, his aptitude for the job, and then his general physical suitability; his temperamental suitability as far as it can be judged, and his willingness or desire to learn. Many of these qualities are imponderables, and we can only judge and assess them without actually measuring them.

Now the job itself for which he is to be trained. We need an accurate description of it, and from examination of this are able to determine what the man must know and do before he can actually do the job efficiently.

In this way it is possible to decide what must be taught, and this in effect is the training need.

This concept of training is just the same whether it be a Stone Age Papuan being trained to do a simple task at the well-head, a Marsh Arab who is becoming a welder, a young apprentice learning to become a skilled artisan, or a graduate scientist who requires advanced training in the latest techniques and trends in automatic plant control.

In all these cases careful initial selection is naturally very important, for it is at this time that we must assess the man, his intelligence, his ability to learn, and his suitability for the job.

Then it is necessary to see that the gap to be bridged is not too wide or too narrow. If too wide it becomes too lengthy a job to train the individual, if not impossible, whereas if the gap is too narrow the job is too easily learned and there is boredom and a waste of manpower. Many training schemes fail because the gap is too wide, and the training need too great, and failure to recognize this has often proved fatal to a training scheme and disastrous to human and industrial relations.

In the first of these cases, that of the Papuan, it may be that he is illiterate, with limited knowledge of any known language and little or no knowledge of the modern world. He will, however, show some sign of native wit and show keenness and willingness to learn. The job selected for him to do will be at first a simple one, such as driving a truck or maybe operating a pump; this ensures that the gap is not too wide and for him is bridgeable. When he is trained, and he will learn quite quickly, he will then have the satisfaction of being able to do a job which builds up his self-confidence and prepares him for his next stage of development.

In the case of the Marsh Arab, we will very likely have a cheerful individual, illiterate but used to the trappings of Western civilization (cars, planes, and films). He requires training in the simple techniques of welding, say on pipeline work, which he can learn quite easily. The incentive is good, for his skill as a welder has good market value.

In the next case, that of the young apprentice, initial selection is again important and we must make sure that the lad is sufficiently intelligent, so a basic minimum of education is required. Aptitude tests may have to be devised and used, and again the lad's keenness and willingness are important factors.

What he must know to become a good craftsman is in itself not difficult to define and set down, and again it is not all that difficult to teach the essential skills of fitting, machining, welding, etc., which can be taught effectively in a relatively short space of time, but what does take time and requires very careful attention, in the case of a young apprentice of this kind, who is most likely quite new to modern industrial conditions, is his getting used to working with people of all ages and getting to know and recognize where and why to apply his newly-acquired skill in varying or different surroundings, learning about the industry and its extremely complex organization. During this time he is faced with radical changes in his environment and in his development from boyhood to manhood. These human factors and changes are the vulnerable and important factors in his apprenticeship and are really the reason for the long term of a four- to five-year apprenticeship, rather than the technical or skill content.

It has been shown that the total skills of an average apprenticeship can be taught and learnt in something approaching six months. This was illustrated in part during the war years when training methods were improved and training programmes accelerated. However, the whole craftsman, who understands "why" as well as "how and what," cannot be trained in six months. In this connexion, however, it may be well to examine traditional apprenticeships, which at present occupy five years, and consider how they may be reduced in time.

The whole question of apprentice training, whether for craft or professional training, is a special kind of training need which in itself is well recognized, and much work has already been done in this field, where the apprentice learns by doing a series of jobs and so acquires the total skills of his craft or profession.

The problem of keeping the young lad with his recently-acquired skill fully occupied, productive, and at the same time satisfied, is a difficult one and not always recognized, let alone solved, with the result that early frustrations are experienced by the young craftsman, and soon there may emerge industrial relation problems, unrest, etc. Much of the responsibility for recognizing and dealing with this wide range of problems of change in the young adolescent worker lies with the foreman or supervisor who is responsible for training the young apprentice and the influence exerted by the foreman during the apprenticeship

period can be lasting and may influence the course of the young lad's career.

The foreman's job is becoming increasingly complex and he will need help from management in dealing not only with the problem of instructing apprentices and his subordinates, but also with the human relations and technical problems on his job. This is mentioned in greater detail later. These remarks apply equally to apprentice training in the U.K., as well as overseas.

Finally, the last example is that of post-graduate training of a science graduate who is to become, let us say, a control instrument engineer. The individual in this case is of high intelligence and academic standard and is the product of a more sophisticated order and environment. However, the training need is approached and defined in exactly the same way.

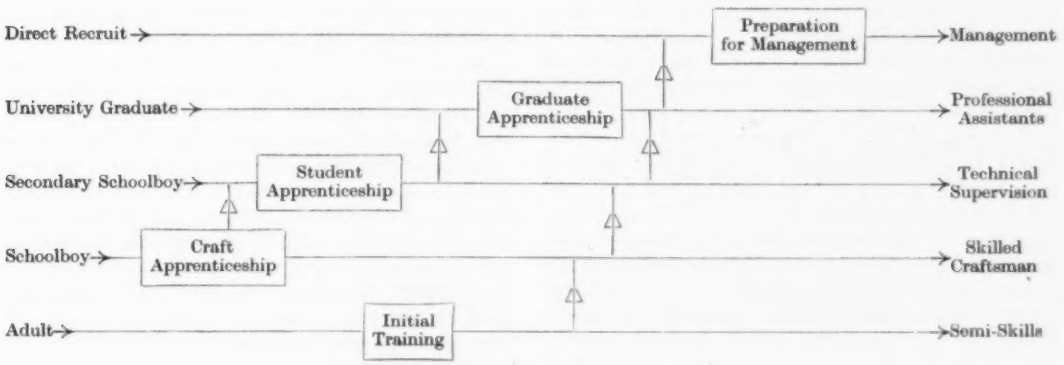

FIG 1

PROMOTION CHART SHOWING INTEGRATION OF TRAINING AND WAY OF PROMOTION BY ABILITY FROM EACH LEVEL TO THE NEXT UP TO MANAGEMENT. THE TIME BASE OF THE CHART IS FLEXIBLE

The graduate may have a degree in physics or electrical or mechanical engineering. The objective, that of a control instrument engineer, requires a knowledge of the fundamentals and techniques of control instrument engineering, plus experience of the operational and control problems of process plant.

It may be of interest that the present control engineering post-graduate course at one of our universities has been developed along these lines, and as such is part of an integrated course which covers the gap between the science graduate (whatever degree he has taken) and the control engineer.

In addition to the gap that is filled in fundamentals and techniques, latest trends are observed and discussed. It also will be necessary for the graduate to obtain operational experience on plant and to experience development problems on plant control.

INTEGRATION

So far we have dealt with training needs at different levels and in different environments and have tried to show that at each level it is important that the gaps that have to be bridged are bridgeable and that there is sufficient incentive to encourage the individual.

It is also necessary to ensure that there is a way of promotion from one level to the next by merit and ability. For example, the semi-skilled worker should have the opportunity of progressing to the next higher skill.

Apprentice schemes should be so co-ordinated and integrated that there is promotion from craft to student apprenticeship and from student apprenticeship to graduate level. In this manner there is a way up for the man of ability who is prepared to work, and the provision of this incentive enables the individual to be developed to the full extent of his talents and initiative (see Fig 1).

Ideally it is believed that this integration should go on right through the full range of training, as it then provides an incentive at each level which can be seen by the individual as something within reach and not vaguely in the distant future.

TRAINING NEEDS AT DIFFERENT LEVELS

The training need referred to so far is in the main for those who are starting in industry, and after their initial training, whatever it is, is completed, they will have bridged the first gap and are settling down to doing the job of work. This may be for many years, even for the rest of their useful lives. There are, however, subsequent gaps which confront the individual who is to progress up the ladder from one job to the next, from a skill to supervision, from supervising post to management, and so on. These gaps are company-made, and it is necessary to ensure that in the structure of the organization and pattern of career development they are not too wide, otherwise frustration of individuals will result.

Training can help to bridge these gaps by providing

opportunities for the individual to widen his experience and usefulness. These opportunities must also be provided at the right time, for if a person remains too long in one job it may be difficult or even too late for him to move out and so broaden his experience in preparation for his further development.

The broader experience that may be necessary will mean spending a period of time working in other departments, or it may even be a question of going overseas.

Alternatively, it may be necessary for the individual who works overseas to come to this country or to whatever country the headquarters of the organization is in, with the object of meeting his opposite number, and sometimes exchanges of this type produce some very salutary effects with more and better understanding the result.

These moves must be made, if they are to be made at all, with great care, and the man chosen for them selected with forethought.

Whilst apprenticeship and short training courses may bridge the initial gap, and so prepare the individual for his place in industry, the question of this further progress over the succeeding gaps, be they wide or narrow, is an important one which has to be viewed not only over the organization as a whole but also from the viewpoint of the individual and his development. In this case training becomes a continuous function which is tailor-made to suit the individual and is better described as career development, which is dealt with in detail in the second paper.

RELATIONSHIP BETWEEN VARIOUS TYPES

So far we have considered the various gaps and the training needs of the individual as he progresses from his entry into the oil industry to his first job, whatever it is. It is now in order to consider for a moment the various types of people in their different environments.

We have referred to the university graduates in one environment, the apprentice, the Arab, the Papuan, and so on. The concept of the training need for each has also been commented on. The approach of the persons responsible for training to the training need of the different individuals in their different environments is very much the same, although the methods of training and incentives employed may vary considerably to suit the circumstances.

This is a most important point which has to be particularly borne in mind when training overseas in an under-developed country, where so often a person is selected to do the job of a training officer for his intimate and lengthy knowledge of and sympathy for the native; very often this is a welfare interest which, although in itself is desirable, is inadequate without knowledge and appreciation of training method.

It should be made clearer what is meant by this approach or attitude of the training officer to the training need of the individual. For example, it will be necessary for him to give heed to the social background of the individual to be trained. He must be aware of custom, taboo, and religion. Then against this background he will decide on the most suitable and appropriate training methods to be used. He will recognize these as difficulties which require his understanding and the understanding of the supervisor who is going to do the training, not as signs of inferiority of intelligence and ability, which can make a man untrainable.

He should as a result be prepared to go back to simple fundamentals, or at least as far as is necessary to meet the requirements of the individual.

In planning the training of an apprenticeship for either a Persian or a British lad of about the same age range, the similarities of the problems one encounters are much more striking than the dissimilarities.

The plan of training follows much the same pattern, the initial basic training, job rotation, and the necessary technical education are really much the same in both cases—the main differences are caused by language difficulties, where the native language, although it may be mature and rich in literature, background, and culture, is not adequately equipped in technical terms. Therefore resort must be made to a modern western language, and one can say that English is the language of the oil industry. So teaching of English very often forms an important part of a training programme overseas.

In most other respects, however, the approach is much the same, and it is still a question of taking the individual, assessing his intelligence, suitability, and present knowledge, evaluating the job he has to learn, and then deciding on how the gap between these two will be bridged.

RECOGNITION OF THE NEED

Whereas there is very often a recognition of the need to train, it is not always apparent to management where this gap is to be bridged and that training can help to meet this need.

In the case of a young lad who wishes to become a craftsman or technician, it is now well recognized that a craft apprenticeship of some four to five years will help to bridge the gap, and it is something that is accepted traditionally in many countries—the same thing is not so easily accepted or even recognized on the commercial side, and although commercial apprenticeship has started in the oil industry to meet the needs of the commercial, shipping, distribution, marketing, and administrative side, it is still in its infancy and has yet to become recognized. It can be added that commercial apprenticeship schemes have so far produced excellent results and are helping

to produce men with the right professional training and with the appropriate oil background.

Again, in the case of work which is intricate and where jobs have to be carefully integrated, such as in process plant operation, the need for thorough and careful training is recognized, but in the case of simpler operations, such as on oil movements or straightforward boiler firing, it is often considered that they can be picked up quite easily in the course of time.

In cases like this the recognition of the need for training may become apparent to one department after they have seen the benefits of training in another department and so as a result steps are taken to organize a suitable training programme.

In the case of graduates, there has been a growing appreciation of how best to train and use science graduates so that they become quickly productive and efficient, and also take on responsibility at an early stage. In this way the training need is becoming better understood, but the position with the arts graduate is a little more difficult, and there is still a large gap to be bridged between the graduate on first entering the industry and his filling a job effectively on the commercial and administrative sides. One of the main difficulties here is that there is still a lack of understanding by management and also by the graduate himself, who wants to run before he can walk and is generally unable to learn the basic tasks of his trade or profession in quite the same fashion as his science or engineering graduate counterpart. The office atmosphere appears to be a more difficult one than the workshop, laboratory, or plant.

In all the above cases, the recognition of the training need comes best from management itself, from heads of departments, and from supervisors who should be in the best position to know the strength and weaknesses of their immediate subordinates and of those they employ.

However, if this recognition is not forthcoming it becomes the training officer's task and responsibility to help to show that there is this need and so get it recognized. He must do so clearly and with much tact and patience. In this situation a great deal depends on the initiative and general acceptability of the training officer, for he must not invade or encroach on the field of responsibility of departmental management. The need is more often brought about by the example of beneficial results of training in other departments than by any form of exhortation or persuasion by the training officer.

Very often the need to train is more clearly apparent in some situations than others, as in the case of the commissioning of a new plant, extension or expansion of existing plant and organizations, or the need to increase efficiency or productivity.

Full employment has resulted in a general all-round shortage of suitable recruits at all levels, and it has been found that a well-planned training scheme offers much that is attractive to the recruit, particularly the one who wishes to make his career in the industry.

It is necessary also to mention that once there is a clear, albeit belated, recognition of the need to train, there can also develop an over-enthusiasm for training; the results and benefits of the first fruits of training are experienced and there then appears an over-elaboration, with all the frills and furbelows of over-training which can bring discredit and even cause serious disruptions in an organization.

Care must be taken to ensure that any scheme of training is kept within reasonable bounds. It is again the training officer's responsibility on these fairly rare occasions to make sure that the training need is seen in its correct and true perspective.

THE TRAINING OFFICER AND HIS PLACE IN THE OIL INDUSTRY

Much of what has been said so far can lead logically to the definition of the role and duties of the training officer and his place in the oil industry. His job may be defined as follows:

(1) *To Help Supervisors and Management Recognize the Training Need and to Define it with them.*

Ideally in certain rare cases the need for training is so well recognized that management approaches the training officer and asks him to produce a plan for action which will meet the situation. However, it is not always so, and, as has already been shown, the training need is often brought to management's notice.

It is not always what has to be done, but when; timing is important. Training always takes time, sometimes a matter of years has to be borne in mind, and it is often the training officer's task to bring the need to the notice of the management in good time, a task which is not always easy to accomplish. He must have sufficient appreciation and knowledge of the situation and sufficient purpose to make his case effective.

Once it is agreed that training is essential, it is also necessary to define what must be taught. This requires, first, an accurate description of the job content; a job description is necessary, and it may range from something quite simple, such as tank dipping, to something quite complex, such as the job of control instrument engineer or a technical sales representative. This job description determines the type of person to be selected for training. From the knowledge of his present existing skill, ability, and intelligence, it is then possible to determine the content and extent of the training need.

The definition of what the job is and what must be taught is principally management responsibility. In the case of the individual to be selected, this is very often decided by the material available, whatever it is.

(2) *To Guide and to Help the Supervisor Plan the Training*

Most supervisors and managers need help in planning and organizing a training programme. After the content of training has been agreed it must then be decided where it should take place and who is to do it, how long it will take and the general planning and sequence, and what methods of training will be employed. In each case there is no hard and fast rule, and the situation will decide what is appropriate and most suitable.

As far as possible the training officer's attitude to the training problem should be as flexible and as adaptable as the occasion demands, and he should be sufficiently resourceful to be able to suggest alternative solutions, if for any reason the existing plan is inadequate. It is generally accepted that the best way to learn a job is by doing it. So, as far as possible, training should be done on the job, and it should be carried out by the line management, or supervisor, who is responsible for the individual. The training officer's role is an advisory one, and he should not do the instructing or training himself if he can possibly avoid it.

He is, however, responsible for the methods of training used by the supervisor, and in planning a training programme he must bear in mind such things as where the training should take place, how long it should take, the correct sequence of training, assessment of training progress, grading, selection, and correct placing of trainees on completion of training.

(3) *To Instruct and Aid the Supervisor in the Art of Instruction*

Most supervisors require some assistance, not only in planning training, but also in instructing and imparting knowledge. Instruction may be carried out in different ways, and for a person to learn how to do a job efficiently he will need to know first of all exactly how he is to do it and in addition will also need to know about the factors outside the job that affect the job and his performance. In other words, he will need to know " why " as well as " how and what " to do.

Direct instruction will give him many of the answers; this may be done in groups or singly. The former gives him the chance to learn the background to the job and to discuss it with others, whilst the latter gives him the opportunity to concentrate on his own performance.

The supervisor will therefore need to know how to deal with group and individual instruction techniques, as well as the method of teaching by lecture and general discussion.

The training officer should be able to instruct the instructor in these skills of training and to aid him whilst he is actively doing it.

The supervisor will also need instruction in methods of selection of trainees and assessment of their progress. The training officer will be responsible for seeing that he gets this instruction.

There are many aids which can facilitate and improve the supervisor's ability in instructing, including audible aids, such as the synchrophone and tape recorder, and visual aids, one of which, the film, has played an important part. These aids are dealt with in the third paper. The training officer should have expert knowledge of the correct uses and limitations of these and be able to advise on them and to arrange for their supply if necessary.

(4) *To See that Training is in Fact Carried Out*

All the training, planning, method, and aid is of little avail if, in fact, the supervisor does not follow it through thoroughly. It is the training officer's responsibility to see that supervisors carry out the training programme quickly, efficiently, and cheaply, and this is probably one of the most important and difficult of the training officer's responsibilities. For this training to be effective it is necessary that, first and foremost, management support it, and that this support is active and not merely lip service. Secondly, it is necessary that the training officer does his part of planning and co-ordinating. Thirdly, the training officer must be acceptable to all levels, and particularly to those supervisors who are carrying out the training programme.

Given these three conditions and people to train, all should go well and the training officer's task of following up and assessing progress should not be so difficult, but in practice, with the day-to-day hurly-burly, there are always snags, and the training officer will need to exercise tact, patience, and drive in the right dosage and order.

Many schemes of training, some quite elaborate, have failed for lack of follow-up and inspection by the training officer. Early initial enthusiasm is necessary when a project is started, but it does not sustain long-term effort, and it is in situations like these that the training officer must show more than the usual optimism, effort, and enthusiasm.

(5) *Organization of Courses*

Finally, he should be capable of organizing group courses. As the organization of the oil industry grows and expands it is becoming increasingly difficult to communicate ideas from one centre to another, and in the interests of developing the individual it may be necessary to bring people together who have common problems, and who work in centres many miles apart, if not in different countries.

The training officer will need to organize courses where new techniques are taught and discussed and where there is an interchange of ideas which can help to develop the individual by broadening his knowledge and so improve his attitude towards his job, as well as his ability to do it.

Examples of this range from courses in marketing

and reservoir engineering to courses in human relations and rapid reading. There are advantages and conveniences in making such courses residential and so the establishment of the residential staff college has been seen in recent years.

In seeing that the above five points are covered, the training officer will be co-ordinating the general pattern of training and so ensuring that it is in balance with the present and future needs of the industry as far as he can see them.

Altogether, it can be seen from these salient requirements that the training officer's job is to create in management the right attitude towards training and to create in the oil industry the right atmosphere in which training can take place.

FUTURE TRENDS

As to the future, the oil industry should have little difficulty in attracting men of good quality, as the jobs it offers are varied, and can be very rewarding and satisfying. There has always been in the industry a romance, a challenge, and scope for those who are keen and have initiative.

With the establishment of student and graduate apprenticeships the entry into the industry will become more and more through these channels. Further and greater demands will be made on the schools, colleges, and universities to supply the right type of man to fill these jobs.

The industry needs, above all, the educated man, be he scientist or administrator, educated in the modern sense that he meets the all-round demands of modern industrial conditions. Closer co-operation will therefore be necessary between the industry and the schools, colleges, and universities, who are responsible for this education, so that they may recognize the need of the industry and the type of education that is required.

THE USE OF FORMAL TRAINING SCHEMES AS A FACTOR IN CAREER DEVELOPMENT *

By R. S. BUTLER †

INTRODUCTION

THE first paper has fully explored the concept of industrial training needs and their occurrence in different forms in many diverse locations where the oil industry operates. The methods were described by which one can recognize these needs and the individual differences in the kinds of people employed.

Finally, the duties of the training officer, and his place in the oil industry in relation to these needs, were set out under five main headings :

(1) To help supervisors and management recognize the training need, and with them to define it.

(2) To guide and to help the supervisor plan the training.

(3) To instruct and aid the supervisor in the art of instruction.

(4) To see that training is in fact carried out.

(5) To organize courses.

This paper is concerned with examining in further detail the role which formal training courses can play in meeting these needs and the work of the training officer in bringing them about. To establish the right perspective from the outset, it must be said at once that whatever benefits may be recognized in formal group training, there can be no doubt that the greatest contribution to an individual's skill and development can come only from continuous assistance and guidance while doing his job. Formal courses are, therefore, seen as an important, but not the only part of the overall structure of a company's training activities.

MANAGEMENT'S RESPONSIBILITIES FOR THE PLANNING OF TRAINING

Everybody will agree that it is part of the essential nature of management to have foresight and plan for future operations. This, above all other functions, lies at the centre of a company's policy-making organization. At board level decisions concerning future production or selling policy are inextricably interwoven with questions of the profitability of different operations, and the provision and sources of future capital requirements. But to plan the physical equipment for the future, and to neglect to provide concurrently for the availability and development of people to operate it, will surely result in the negation of planning—new plants and no operators.

MANPOWER BUDGET ANALYSIS

Concurrently with the preparation of physical and financial budgets, there is a need, therefore, to budget for future manpower requirements by different

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† Esso Petroleum Co. Ltd.

categories and locations of all the kinds of people who will be needed in the industry—chemists, engineers, accountants, salesmen, supervisors, draughtsmen, plant operators, drivers, and many others.

Stock can be taken of manpower requirements in convenient and practicable periods of five years. The analysis can be made under two headings:

(1) Increase to existing staff.
(2) Replacements necessary over this period to make good losses due to:

(*a*) promotions;
(*b*) resignations from the company;
(*c*) retirements.

If different methods of operation are to be introduced during this period, a review of manpower requirements to continue present operations by different methods will also be required. One has in mind the application of electronic engineering to accounting procedures and the extension of automatic processes to the operations of terminals and installations.

From a study of the figures which emerge from a manpower budget it will be apparent that a great number of similar changes from one level of job to another, whether sideways or upwards, will take place. An assumption is implied here which is fairly widely accepted in the oil industry—that future manpower requirements for the oil industry are largely provided from internal promotion. Experience has shown that the oil industry is very much a career industry for those who make it so. It is only when an exceptionally disproportionate growth of a specialism takes place, or when a new technology is introduced, that highly qualified and experienced people from outside have to be brought in above the normal junior levels of recruitment.

STRUCTURE OF CAREER DEVELOPMENT

Working on this assumption, it is possible to put forward two of the main structures of career development in one company in terms of distinctive categories of jobs linked to each other, yet involving a "threshold" of increased, or different responsibilities, to be crossed on each occasion.

(1) *The Sales Recruit to Sales Management*

Salesman
Administrative Assistant
District Manager
Product Manager (Division or Head Office)
Divisional Manager
General Sales Management

(2) *The Specialist through Supervision to General Management*

Engineer, Accountant, Purchasing Assistant, etc.
Section Head
Senior Supervisor
Junior Manager
Manager of Minor Department
Assistant Manager—Major Department
Head of Major Department

IDENTIFICATION OF TRAINING NEEDS IN A STRUCTURE OF CAREER DEVELOPMENT

If these broad distinctions of categories of position are accepted, then from the apex of a large organizational structure, such as a refinery department or a general sales department, a large number of promotions into each of these categories can be seen to be necessary year by year. The people available to receive these promotions can also be identified and in respect of each stage of career progression the training formula

WHAT THE JOB WILL REQUIRE	Minus	WHAT THE INDIVIDUAL KNOWS NOW	Equals	HIS TRAINING NEED

can be applied. Naturally, whilst many positions are similar, each will have certain characteristic requirements of its own. Likewise, individuals will be at different stages of readiness in relation to the requirements of future promotion. Whilst there will, therefore, be differences in each individual's residual training needs, there will, however, be a large measure of overlap.

THE RATIONALE OF GROUP TRAINING COURSES

It is this existence of training needs in common amongst a large number of people just, or about to be, promoted to similar positions which provides the rationale of group training. Two cases can be taken to illustrate this purpose in detail:

(1) *Administrative Assistant to District Manager*

In the course of the next five years many appointments to District Manager will have to be made in the company for which the author is working. A district manager is responsible for an area of several counties and directs the efforts of twelve to twenty salesmen and several bulk plants. The most likely people to fill these vacancies are the administrative assistants in district offices with some years of experience in the different fields of marketing sales. Applying the formula—what the job requires minus what the individual knows now equals his training need—to this

position, we have found that, due to a lack of opportunity, there are gaps of knowledge and experience in the following subjects :

The Conciliation Agreement and Labour Relations
Head Office and Divisional Sales Organization
Physical Operations
District Manager's Responsibilities for Training, Communication, and Public Relations

After identifying these needs, the question " How can they be met ? " must be asked. Several choices are open, namely :

(*a*) Individual coaching of each assistant by his immediate supervisor, the district manager, as and when time permits.
(*b*) Group training, either at spaced intervals or intensively on a residential basis at divisional office.
(*c*) Residential course at the Company Training Centre.

As the second choice is something of a compromise between the first and third, we can best see the advantages and disadvantages of the alternatives by comparing only the first and third.

INDIVIDUAL COACHING ON THE JOB

Advantages	*Disadvantages*
1. Immediate supervisor carries out his responsibility for training.	1. Result of instruction will largely depend on knowledge, experience, and attitude of one instructor on all subjects.
2. Can illustrate instruction with local cases and problems.	2. Overriding demands of normal work may cut across instructional requirements.
3. Permits maximum questioning by learner.	3. Instructor's experience may not be wide enough to answer all the questions.
4. If instruction is given when work load is light, results in minimum interference with normal work.	4. Aids to sound instruction, *e.g.* ideal physical surroundings, visual aids, etc., are absent.

RESIDENTIAL COURSE AT THE COMPANY TRAINING CENTRE

Advantages	*Disadvantages*
1. Opportunity of obtaining ideal learning conditions —no interruptions.	1. Appears to abrogate line management's responsibility for training.
2. Widest range of instructors to choose from.	2. Can create a feeling of remoteness from day-to-day problems.
3. Continuous residential contact maximizes benefits from wide range of ideas and experience (cross-section of company) of course.	3. Instructors may be drawn too exclusively from Head Office.
4. Enables a " taking stock " process to be started by the individual.	4. The dilemma of sending a " changed " man back into an " unchanged " environment.
5. A " morale builder " in a general sense.	

A comparison of these approaches, essentially from the viewpoint of the learner, shows that the advantages appear strongly in favour of the residential course. From the point of view of General Sales Management, there are two other very good reasons in favour of the residential approach, namely :

(*a*) It enables a reasonably uniform exposition of the company's sales objectives, policy, and methods to be presented.
(*b*) In as much as the Administrative Assistant's promotion has been largely within the Division to this stage, it better prepares him for his next appointment as a District Manager, which may well be outside his own Division.

(2) *Human Relations Skills for First Line Supervisors*

Following a similar approach, an analysis was recently made of the knowledge and skills required in common by all supervisors at the first level of supervision of staff employees. Again a sufficient measure of common requirements leads to a recognition of the overriding advantages of a residential supervisory training course which currently includes the following subjects :

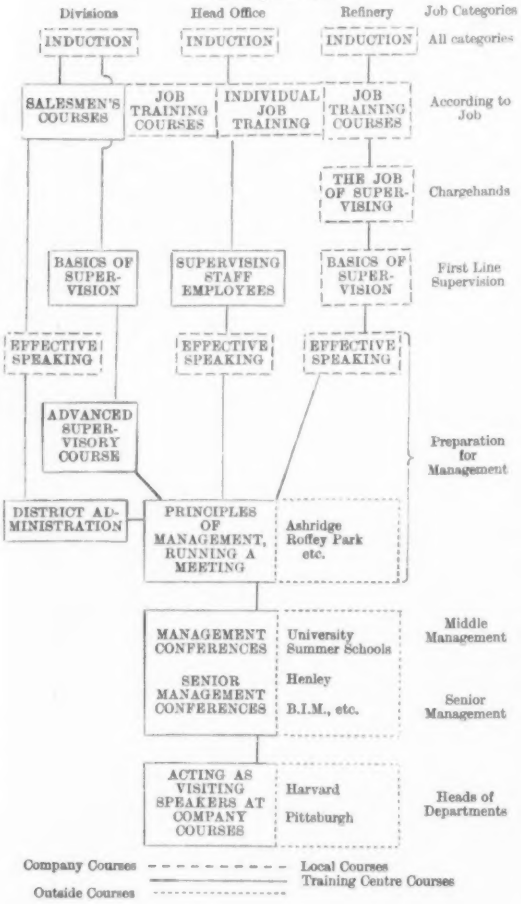
The Elements of Supervision
Job Relations
Problems of Letter Writing
Communication
Conducting and Participating in Meetings
Assessing Job Performance
Cost Control in the Office
Organization and Planning

INTEGRATION OF CAREER DEVELOPMENT NEEDS AND ORGANIZED TRAINING COURSES

When this approach is followed for each major area of training, a structure of courses, integrating the company's facilities with those available elsewhere, will emerge, designed to meet the common needs of numbers of employees preparing for, or recently appointed to, the next promotion. A simplified, and by no means comprehensive, diagram of what this will involve in one company is shown below.

It will be noticed that attendances are planned at company courses for practically all of the employees in a particular category. Attendances at outside courses are on a highly selective and limited basis.

Integration of Career Development Needs and Organized Training Courses



CONSIDERATIONS CONCERNING THE ADMINISTRATION OF RESIDENTIAL COURSES

Nominations

Whilst the description of the purpose and contents of the course and the category of employees for whom it is intended is usually provided for management guidance in making the nominations, actual choice of any individual to attend at a particular time must depend upon the manager's judgment of the circumstances, with which only he is fully conversant. A number of questions will occur to him :

Can he be spared and the work maintained ?

Is a suitable person available to take over his work ?

Do his domestic circumstances permit him to be away from home ?

Is this the right time for him to attend in terms of his readiness to gain maximum benefit from instruction and discussion ?

If he is nominated, but not others, will there be any adverse morale effects in the unit ?

From the point of view of the training staff, careful thought has to be given to ensure that suitable people have, in fact, been nominated. The distribution of vacancies to departments will have been carefully planned, either to obtain a group homogeneous in age, length of service, type of work, status, etc., or an intentional cross-section in terms of these variables. As the nominations are received, their attributes are compared with the intended structure of the course's membership. Misunderstandings can arise on this subject between those organizing courses and those making nominations, and the smoothing out of inappropriate nominations can be a delicate matter.

Briefing

It is desirable, and is usually possible, for a manager knowing the purpose and content of a particular course to describe them to those of his department who will be attending. This prior "briefing" session can contribute to creating an interested and active attitude towards the course in the minds of those attending. It also permits him to relate the course's objectives to the department's work. The manager also gives himself an opportunity to be sure that arrangements have been made for work to go on during absence and that a suitable deputy has been provided.

Administration of the Course

The first important step is to ensure that everybody has settled in and established contact with one another and with the instructional staff. A little time is needed for adaptation to the change in environment, and too much must not be expected from the first few hours of the programme while this process is going on.

From experience it has been found that a number of guiding principles apply to the design and administration of most courses :

(1) Greater learning takes place if members can be involved in full participation. According to the nature of the course and those attending, this may mean discussion work, demonstrations, and assignments to act as chairman for a day, to introduce a guest speaker, or propose a vote of thanks.

(2) Variation in the instructional methods employed, if not carried to excess, makes a useful contribution. Particular methods have their own appropriate uses, and variety of method itself can help to counter the onset of monotony and boredom. Many of the methods which would be employed will be familiar—the lecture and discussion, the case study method, syndicates, demonstrations, role-playing, etc.

(3) Learning is enhanced if it can be absorbed through more than one of the senses. Consequently, visual aids used with discretion can make a useful contribution to all instructional methods.

(4) Variation of " pace " can also provide a stimulus and add variety. Pace of instruction and discussion can gradually be built up over the first day's work to a high pitch on the second day. " Working against the clock " is a training experience in itself, and replicates an all-too-common business situation. A climax of effort in the programme can be followed by a clear break—an afternoon and evening to prevent staleness and anticlimax from setting in. The cycle can then be repeated. Our experience shows that this, if carefully calculated, is a more productive distribution of effort than a uniform pace throughout the week.

(5) Representatives of management, who have approved the course and nominated their staff to attend, have a useful part to play while the course is on. Despite the drawbacks involved, there is a net advantage to be gained from asking a manager to open the course and, where appropriate, to be present for some of the discussions and summing-up periods. The objectives in involving management in this way are—

(*a*) to counteract a tendency to regard training as something that is done in another place;

(*b*) to provide management with an opportunity of observing the programme which it has initiated;

(*c*) to impress, upon those attending, that the discussions are in management's opinion related to, and have significance in, the normal work of the company.

SOME PROBLEMS CONFRONTING THE COURSE ADMINISTRATOR

Bringing together a group of individuals, each with his own unique personality, ambitions, and problems, into a group situation over a period must inevitably create problems. The course administrator will, therefore, need to be aware of the main types of psychological problems which may arise, and be sufficiently sensitive to identify them and take appropriate remedial action. It is not suggested that he must become responsible for solving an individual's personal problems. However, one will, perhaps, recognize the nature of situations which may arise if the following are mentioned :

(1) There may or may not be a company policy—stated or implied—of using the situation to assess an individual's performance. Whatever may have been said to the contrary, it is certain that some individuals will still consider themselves to be under close scrutiny. Their behaviour may be affected, perhaps detrimentally to the value which they would otherwise obtain from the course. It is a common viewpoint amongst training staff that all efforts to use training courses to assess people should be discouraged. Training officers are most anxious to eliminate any suspicion that the students are being " spied upon."

(2) This first hazard and the expected strain of coping with a new situation may mean, for those who have led a very sheltered life in the company, that the course is regarded as presenting a tremendous challenge. If the individual feels that the challenge is too great for his capacity to meet, his anxiety may be such as to cause a minor breakdown. In these circumstances he may have to leave the course before its end or return home. This in itself creates a number of delicate issues :

(*a*) Does the training officer regard this as private information? Or does he consider it his duty to report the fact to the individual's manager?

(*b*) Does this involve " loss of face " for the individual concerned? How does he recover his prestige?

(*c*) If his withdrawal affects the other members of the course, how does the training officer rebuild their morale?

POST-COURSE ADJUSTMENT

It is essential to recognize that an employee will return from a course—for better or worse—a " changed man." His environment—the attitudes of his immediate supervisor, his own staff, his colleagues, the company's policy, regulations, and procedures, etc.—will not have changed during his absence. A process of adjustment is, therefore, inevitable both of the individual to his environment and, to some extent, of the environment to the individual. His immediate manager, if he is prepared for this situation, is the person most able to facilitate these adjustments by his own efforts.

His first step should be to arrange for a discussion with him to obtain his reactions to the course and to measure the extent of change in his knowledge, self-confidence, attitudes to work, and willingness to accept responsibility and authority. There are a number of things which he may wish to consider in order to canalize into productive channels the probable enthusiasm and ideas with which his employee has returned.

(1) The employee may now be ready for further responsibility, additional authority, or larger span of control.

(2) His wider outlook may be sustained by membership of company or outside committees.

(3) He may benefit from encouragement to take up a course of studies for a qualification, or some outside activity.

(4) He may ask for, or be willing to agree with, a transfer to another department or a change of work within his own department.

(5) Changes of attitude on the part of his colleagues or staff reporting to him may have to be discussed with them and appropriate action initiated.

(6) Finally, and perhaps it should have been first, the manager may have to recognize the need for change in himself. If, for instance, the employee has been discussing "delegation of authority" for several days, the manager would do well to ask himself how far he delegates authority within his own department. This can be a very salutary exercise!

CONCLUSION

This paper has been concerned with the contribution of formal company courses to major training needs, and has attempted to set them within the broad framework of training principles, which can be summarized as follows:

(1) Responsibility for analysing training needs and taking steps to meet them rests squarely on the shoulders of every manager.

(2) Training should never be done for training's sake. This applies with particular emphasis to "sending people on courses."

(3) Organized company courses are seen as one of several alternative methods of meeting training needs. Careful analysis of each situation is required to determine whether the objectives, content, and instructional methods of any course existing or projected are relevant to the training needs of a particular individual. If attendance at a course is shown to be desirable, then the actual timing of an employee's attendance must also be carefully considered.

(4) The value of courses can be greatly enhanced if they are seen as a contribution to a continuous effort at personal guidance or counselling by a manager or supervisor of those employees whose work he directs. The opportunities which attendance at a course present, both in a briefing session before and in a follow-up discussion afterwards, are some of the most valuable for this man-to-man guidance.

TECHNIQUES OF PRESENTATION IN EDUCATION AND TRAINING*

By A. I. S. DEBENHAM†

In the minds of some people there is a very real difference between education and training, but for the purposes of this paper it is considered that being educational activities, the techniques of presentation will be common to both.

TWO FUNDAMENTAL TECHNIQUES

It can be said that there are two fundamental techniques:

(1) *Group Instruction*, in which new knowledge is presented to a group of people in a step-by-step logical sequence. The learning is then further increased by the use of questions to get the people under instruction to think about the new knowledge they have acquired and apply it to specific circumstances. Finally, the instructor tests to ensure that the lessons he has been teaching have in fact been learned.

(2) *Discussion Leading*, which is becoming more and more widely known. For this purpose the members of the group must have a certain amount of knowledge of the subject or experience to enable them to contribute usefully to the discussion. In this way their knowledge of the subject can be broadened by learning from each other. Also, a member, when having his ideas challenged by another, will have to think more deeply about his ideas, and in consequence they should become more soundly based and possibly modified.

The separation of these two fundamental techniques in this way is, to a certain extent, artificial, since it is quite possible and frequently desirable to use both of them together, where, for instance, some new material is to be presented to a group which already has considerable experience of the subject; for example, a new product may be introduced into a sales range, and a salesman, although experienced generally in selling the company's products, will know nothing about the new product. Therefore the information about the new product will have to be im-

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† The Shell Petroleum Co. Ltd.

parted to him using the Group Instruction technique, and he will then be in a position to discuss the ways and means of selling this product, applying his sales experience to the problem.

LECTURING

It may well be asked where lecturing fits into this picture. Essentially the lecture is a part only of the Group Instruction technique whereby the use of questions to increase the understanding of the group and the test to ensure that the knowledge has got across cannot be applied, usually because the numbers in the group are too large. This course is apt to reduce the effectiveness of the instruction, and it can be considered the penalty which has to be paid for large numbers under instruction at any one time. On the other hand, it may be that the material being presented to the group has merely an interest value and is presented with the objective of increasing the background knowledge of the subject. In this case the lecture may adequately fulfil this purpose.

To make either of these fundamental techniques more effective, there are a number of aids which can be used, varying from the better-known visual aids, such as the blackboard, flannel board, chart pad, films, and filmstrips, to other aids which are frequently thought of as training techniques in themselves, such as role-playing, visits to factories, or plant and practical work.

THESE TECHNIQUES APPLIED TO THE INDIVIDUAL

We have tended here to consider techniques of training where a number of people are involved. However, the same principles can also be applied when it comes to the training of individuals. Frequently it is necessary, in order to obtain the full value from the training of individuals, that they should both attend the formal type of course as a member of a training group and also be guided and coached in their day-to-day working, usually by their immediate superior. This can almost be considered a technique in its own right, but nevertheless it should embody the principles used in Group Instruction and Discussion Leading; that is to say, if the person being guided has no knowledge of the job or work to be done, then it is up to his superior to present to him the information required in a logical step-by-step sequence, followed by questioning to increase the learner's knowledge and at the same time perhaps to check that the information has gone over correctly. If the learner already has considerable knowledge of the subject, then discussion with him and use of well-considered questions by his superior will help to further the learning process.

TEACHING THESE TECHNIQUES

The Shell Petroleum Company gives a one-week course to teach these two fundamental techniques to members of the staff who are specialists in certain subjects and who are called upon to impart their specialized knowledge to personnel attending formal training courses. First of all the Discussion Leading technique is demonstrated and then the principles are discussed with the members of the course, who prepare to take a practice session the following day. Each member has 30 minutes in which to handle a discussion. After each practice the course member's performance is constructively criticized by the group, led by the instructor, so that all can learn as much as possible from it. This is followed by a demonstration of the Group Instruction technique with practicals and discussion on the practicals as for the Discussion Leading technique. The use of training aids is also discussed during the week as opportune, but in view of the amount of time available the fundamental techniques are concentrated upon in order to ensure that they are thoroughly understood, because it is believed that if this is achieved the instructor will be able to make use of any available aids more effectively.

It has been shown that a well-founded skill in the handling of these techniques helps an instructor to make better use of the lecture and also of advanced techniques, such as the case study, and other aids to training, such as role-playing.

THE CASE STUDY

It may be interesting here to note that case studies were first used at Harvard for the study of law, recorded court cases being used for the purpose. It was then considered that this might be a useful way to teach management principles and practices, and consequently a number of industrial situations were written up into case studies for discussion, these studies being based on real-life situations involving certain management principles and practices.

Case studies have been used by Harvard Business School for a number of years, and it is fair to say have proved an extremely valuable teaching tool. More recently in the U.K. a number of people have been writing cases and using them for training in different ways. First of all the case has to be presented to the group. This can be done by:

(1) word of mouth;
(2) hand-out, with or without illustrations or diagrams;
(3) recordings;
(4) filmstrip with recording;
(5) film;
(6) demonstration using role-playing.

The type of presentation selected will depend upon a number of factors, such as the length of the case

study, its complexity, and the composition of the group. It is also possible for a member of the group to present a case study of his own or for the instructor to present a case study in part only and then allow the group to extract the rest of the case study from him by question. This is sometimes called the incident method. After presentation by one means or another it is usual to discuss the case with a view to the participants learning some lesson from it, increasing their understanding of some particular aspect of management, and helping them to make sound decisions based on a thorough analysis of the situation.

Good use has been made of the Industrial Welfare Society filmstrips, which have been found to appeal not only to the lower levels of supervision but also to members of higher management. It is felt that both the short case, which may consist of one or two pages of print or three or four minutes of filmstrip and recording, can be just as valuable in its own way as the lengthy and well-documented case of up to forty or fifty pages, with supporting appendixes.

Experience has shown that for an instructor to get the full value from a case study it is necessary for him to have a considerable knowledge of the individuals in his training group and for him to be skilled in Discussion Leading. He needs to be a good listener and to have studied the case thoroughly himself, and he will also need to have a good understanding of the basic principles and practices of the subject which he is trying to teach. If cases are to be used for studying specialized subjects, *e.g.* finance, then he requires a good grounding in that particular subject.

There may be some people who would disagree with these requirements on the assumption that all that is required is someone who can chair a meeting, see fair play, and summarize at the end. While it is probable that the group might still learn something from a case handled in this way, it is felt that they would still not get the maximum benefit unless the instructor knows what is in the case and is able to understand what the members of the group are saying. He will not be able to ask questions which will force the individual members to think more deeply about the problem involved or put them in such a position that they will see that certain of their thinking is faulty. This understanding on the part of the instructor is also required to help the members come to a decision. A group may well avoid coming to a decision or really getting down to analysing a problem unless the instructor understands what is going on and by suitable questions or statements forces the group into really getting down to work.

An important aspect of the use of case studies is the selection of the case material itself, quite apart from its form and presentation. Should it be selected from a source outside the company and, if it is, should it be an American or English case or from some other country? The experience of The Shell Petroleum Company has shown that many of the cases published by Harvard in *The Administrator* are very valuable teaching tools, and the fact that they are drawn from American industry does not detract from their usefulness. Not infrequently course members recommend that English cases should be supplied, but it has been found that the more mature groups quickly get to grips with the problems involved, regardless of the origin of the cases, and find that, provided there is intrinsic value in the case, it does not really matter from which part of the world it comes. The same sort of sentiment applies to those people wishing to have case studies from their own company. It is not necessarily true that a company's own cases form good teaching tools, and in addition there is always a danger of emotional factors entering into the discussion because a member of the group recognizes the case as a situation in which he cannot be impartial and in which he may actually have been involved. There is sometimes a tendency here for the criterion of the value of the case to depend less on its usefulness for teaching a lesson than on whether it comes from the company or not.

The following anecdote may help to illustrate that American cases are not so inapplicable to British training. A member of the instructing staff and a member of the training group were discussing in a train one of the Harvard cases published in *The Administrator* which had been used during a course in which this particular pair were involved. This discussion was overheard by one of the more senior executives in the company, who reported to the Training Officer that certain members of the training staff were discussing company problems in the train and that this was highly undesirable!

ADJUNCTS TO TRAINING

(1) *Role-Playing*

The term " role-playing " is used here to cover any type of situation in which the instructor or individual under training is called upon to play a part. Other names for this type of activity include socio-drama and psycho-drama. Role-playing can be an extremely valuable teaching tool, but at the same time there are certain dangers inherent in using this technique. There are five main uses to which role-playing can be put:

(*a*) to demonstrate a point
(*b*) to give experience and practice in handling human relations situations
(*c*) to give experience of " the other man's point of view "
(*d*) to try out a decision based on a case study
(*e*) therapeutic treatment of neurosis cases.

There is a subsidiary use of role-playing, but instructors should be most careful to ensure that it does only play a subsidiary role. This is the indication

which role-playing can give to the instructor of the effectiveness of his instruction.

One of the more serious dangers here is that the instructor, and particularly outsiders who are not closely connected with the course, may make a judgment on a particular individual's performance in playing a particular role which in fact is ill-founded, because he is acting in an artificial situation and may well not show up in his true form.

Item (*e*) has been included because there is a certain amount of work published on this use of role-playing, and it is important that it should be made clear that whatever the value of this use of role-playing it is essentially a medical technique, and as such should be used only by qualified practitioners. It is not the educationalist or industrial trainer who should be doing this type of work.

Of the other uses there is a fundamental difference between (*a*) and the others, since for demonstration purposes a certain amount of rehearsal is necessary. This means that the demonstration will either have to be put on by members of the instructing staff or the course members will have to be available for a sufficient amount of time for rehearsal, *e.g.* on a residential course, and these factors may limit its usefulness. Examples of this type can be seen in the T.W.I. Job Instruction Programme, where the instructor demonstrates good, bad, and indifferent instruction to the group. It is also used from time to time in the Services to illustrate procedures. It can also be used to demonstrate good, bad, or indifferent handling of human situations, such as a supervisor handling an employee or a salesman visiting a customer (which could if desired be used as case studies for discussion). Clearly these points can be demonstrated in other ways, in particular by film and filmstrip.

However, for this purpose role-playing may have certain advantages—no projection equipment is required, and it can be done in daylight. A particular situation can be demonstrated much more cheaply by this type of role-playing than by having a film or filmstrip specially made for the performance. It makes the demonstration much more vivid than a purely written description.

The other uses of role-playing are essentially spontaneous. That does not mean to say that no training should be given to individuals before they are asked to role-play, and in fact it is normally essential that at least some training should be given so that their performance in the role-playing sessions is not so bad as to destroy their confidence. This destruction of confidence due to the embarrassment of failure in front of the group is one of the ever-present dangers in the use of role-playing as a training tool. Again, this use of role-playing is used in the T.W.I. Job Instruction Programme, where the supervisor is given practice and experience in putting over his instruction to a member of his staff. It is also used in many spheres of training for giving supervisors practice in interviewing members of their staff from different points of view, such as a grievance interview, and also in sales training, where a salesman is given practice and experience in making his sale.

In these instances the "employee" or the "customer" can either be a member of the instructing staff or one of the course members. If he is a member of the instructing staff, then there is clearly more control over the role-playing situations, and consequently it can be used by the instructor to ensure that the particular individual lessons are learned. On the other hand, if these parts are taken by the members of the course, a wider difference in "customers" may well be achieved, and it enables all the course members to gain experience of the other person's point of view.

Role-playing can also be carried out either between all the individuals of the training group at the same time or by having two or three members of the training group out in front of the rest. The latter will mean that the instructor has better control of the role-playing situation, since he can keep his attention fixed on it, and also that everyone in the group can benefit from the lessons to be learned from one particular situation. However, the discussion following the actual role-playing must be carefully led and handled by the instructor to ensure that there is no loss of confidence on the part of the players and that profitable lessons are learned from the performance. If all members of the group are playing a role at the same time, this may reduce embarrassment in that they are not called upon to perform in front of the whole group, but at the same time it means that the instructor cannot possibly know what is going on in each situation, and therefore cannot be sure that the right lesson is being learned.

It is possible to use this type of role-playing away from the group; for instance, the members of the training group can be interviewed by a member of the instructing staff with both of them taking a specific role; in this case the member of the training group could well be briefed by a number of his colleagues in syndicate who have discussed the problem with him beforehand.

Sometimes during a discussion a member of the group may say what he would do if faced with a particular situation. This is an opportunity for the instructor leading the discussion of a problem or case study to offer to play one role and allow the man who has made the statement to try out his line of approach to the problem in a more realistic situation. This allows the member of the training group to test his decision based on the discussion, and it also enables him and the group to see how successful that particular decision was. It is up to the instructor in this situation to decide how much encouragement to give the group member to play the role, depending upon

the individual, where the actions arise during the course, strength of group, formation, etc. The danger of loss of confidence has already been mentioned, and needs to be carefully guarded against. Other more obvious dangers, such as over-acting, bad briefing, unsuitable situation, high tempers, can be overcome by the instructor who is prepared for them.

(2) *Visits*

All too often visits, like other adjuncts to training, are put in a programme to give the instructor a rest from the course, and incidentally to give the course members an opportunity of seeing some aspects of the business or customer's business which hitherto they have only heard about.

It is clear that if a visit is going to aid training the first thing that must be thought of is the objective that the instructor has in mind when planning the visit. What piece of instruction can only be given to the course members in this way? Certain things, such as the complexity of a modern refinery, the cold biting wind that whistles round the cooling towers, can be learned only from experience. Also the size, intricacy, and complexity of such things as a modern refinery are difficult to convey in any other way.

Having decided the objective to be achieved, the instructor must then plan his visit in such a way as to achieve it. He should ask himself such questions as the following: when should the party go? How long do they need for the visit? Could the party be shown round by people locally, or are additional instructing staff required? Will they have to be split into smaller parties? How should they be transported? Can they be got back to their hotels the same evening, if not, what sort of accommodation should be provided for them? Should the instructor go with them himself, should someone else go with them, or is it sufficient to load them into a bus and have them met the other end? Not only do these questions and others need be answered but for a really effective training visit it is also essential that all the administration is faultless and everything goes without a hitch. It is always possible that something may go wrong with even the best-laid plans, so alternative plans should be made to ensure that the training group are not left wondering what to do.

TRAINING AIDS

We now come to a number of things which are referred to by various terms, such as visual aids, audio-visual aids, etc. In this paper they are referred to as training aids, as the important aspect is that they should be aids to training and not become something that is done for its own sake. It is frequently said that there is nothing to beat "the real thing" when it comes to training, but this is not always true, as in the instance of the "Link" synthetic blind-flying trainer, which is a much safer way of teaching instrument flying than flying in cloud. This does not mean to say that the blind-flying trainer excludes actual instrument flying in the air, but it does reduce the amount of expensive and dangerous time required to make a pilot proficient in instrument flying.

Films can also play a very useful part in training, in particular where movement is concerned. There is, however, frequently a danger that films are used just for interest and to make a break or to teach a lesson which in fact merely imparts background knowledge: this is not to say that background knowledge should not be imparted, but frequently the time involved in showing the film for this purpose is out of proportion to the time spent in imparting essential knowledge on the subject. Before using a film as a training aid, any instructor should ensure that he knows why he is showing the film, that he has seen it and knows how this particular film is going to help him to teach his lesson, and that the time required for teaching this lesson in this way is proportional to the value of the lesson learned. He should also consider whether or not part of a particular film could be used, thus concentrating the audience's attention on a particular aspect and also saving time by teaching one specific lesson rather than clouding the main lesson by showing a number of less specific points.

Filmstrips and slides also have a useful part to play in illustrating talks or presenting case studies for discussion.

The blackboard or, as it is sometimes called now that it has green or other colours for its surface, chalkboard, is well-known throughout the world from the earliest school days, and in the hands of a competent instructor can be very effective. Its near relations, in the form of different types of chart, now play a big part in training, varying from the charting of a discussion by means of noting headings on a large sheet of paper, through various types of written and printed charts or, as they are sometimes called, class sheets, to the more sophisticated type of aids, such as the flannel board, magnetic board, and others.

There is a danger that because a particular aid is new to an instructor and appeals to his imagination, or because it has served him well in some circumstances, he tends to use this particular aid to the exclusion of all others. It is essential that to be successful an instructor should know the limitations and advantages of all the training aids at his command and ensure that he does not fall into this trap.

Models, samples, and sections of the real thing can be a valuable aid, particularly for showing how things work. Use is made of model drilling rigs to show the overall picture and sectioned items such as injector pumps for diesel engines to show how the fuel is metered into the cylinder. Many hours of instruction time can be saved by intelligent use of models.

In using these types of aids it is essential that the

instructor should first of all decide upon the points to be illustrated, then select suitable illustrations of what he will use. In doing this he should bear in mind the determiners of attention, size, colour, novelty, contrast, and movement. He should remember the size of his room and the size of his audience. It is very tiresome for a member at the back of the room to be unable to read what is written on the aid. He should plan the presentation of his aid, its timing, who should do it, and whether he needs help, and it is also as well to check any mechanical equipment. A rehearsal will help to ensure that his presentation is good and that no unnecessary hitches occur. He should review or preview films and filmstrips and work out how he is going to introduce them and then recapitulate the lesson afterwards. He should use his plan intelligently to present his aid but be ready to change should he find this necessary. Finally, the instructor should check to see if it will be possible for him to improve the timing, layout, presentation, or effect. Would a different type of aid be better? One should not always use the same type of presentation. Excessive use of one particular type of aid should be watched. A training aid is apt to become a liability if it is not removed when it is finished with, since it may detract people's attention in the wrong direction. A short list of possible aids to training is set out in the Appendix.

CONCLUSION

In this paper the aim has been to show that there are two fundamental techniques of training—Discussion Leading and Group Instruction—which should first be mastered by the instructor. These will form a sound foundation on which he can build his instructional work. Further, if these are considered as fundamental it will help the instructor to understand what lessons he is trying to teach and what training objectives he is trying to achieve. Then, having understood this, he can make suitable use of all the other training tools available to him in such a way as to make his training as effective as possible. Any other approach is liable to lead to confused thought in the mind of the instructor, who may well be led up blind alleys where the aims of training are considered as the end.

APPENDIX

(1) Stories and descriptions—mnemonics
(2) Illustrative hand-outs—notes taken by the group—manuals—reference books
(3) Blackboard or chalkboard
(4) Chart pad
(5) Charts and class sheets: enlarged photographs—diagrams—organigrams—graphs—figures—maps—line drawings—sectional drawings—moving diagrams—list of points—flannel board—Zell-Em—magnetic board—flop over—strip-tease—slotted board—transparent covering (enlarged facsimile form)—built up of transparent sheets
(6) Wall sheets and posters
(7) Sound recordings
(8) Episcope: the real thing enlarged, *e.g.* leaf and caterpillar—illustrations from books, periodicals, etc., enlarged
(9) Overhead projector (Belshazzar) } Back stereoscopic and stereophonic projection
(10) Slides } Back stereoscopic and stereophonic projection
(11) Filmstrips—cyclic (loop) } Back stereoscopic and stereophonic projection
(12) Filmstrips with recording } Back stereoscopic and stereophonic projection
(13) Films: silent—sound—magnetic track—loop } Back stereoscopic and stereophonic projection
(14) Visual unit
(15) Closed circuit television
(16) Visits: plant—exhibitions—museums—trade fairs
(17) Practical work
(18) Competitive activities
(19) Role-playing
(20) Demonstration
(21) Samples
(22) Models: small—enlarged—working—sectioned
(23) Synthetics, *e.g.* "Link" Blind-flying Trainer
(24) The real thing—sectioned—seen through stroboscope—exhibits

DISCUSSION

F. H. Perkins: By taking these three papers together, a very comprehensive survey is provided. There is evidence in all three of observations born of sound practical experience, and the papers are worthy of further circulation among people in industry, especially those who are particularly concerned with the development of training in industrial companies.

In regard to more general points, the value and success of the work to which the speakers refer will depend very largely on the extent to which the activities they have described are interwoven into the whole personnel policy of a company. There are real dangers when training becomes a profession on its own, with the jargon and theory that only specialists are entitled to understand. The development of satisfactory training schemes requires a foundation of the theory outlined in the symposium, with particular regard to the establishment of training needs, as mentioned in Mr Stephens' paper. I am not sure, however, that there is a great deal of wisdom in pressing that theory across to busy managers themselves, because the developments that can take place on the basis of that theory would be largely governed by the extent to which managers will be convinced by and in sympathy with what is suggested should be done. After ten years of experience in ICI as Education Officer, I find that the soundest developments have arisen from very close collaboration between the personnel side and executive management, assessing the sort of steps that can be taken and establishing the best ways in which executive management can be kept fully *au fait* with the objectives and value of specific training developments. I would be prepared to surrender some of what one might call the "stylized" approach in the interest of expedients that might convince a rather reluctant manager that any work of this character can be of assistance to him. That is my first general point, but before leaving it, I would like to express the hope that, in the years to come, we might almost forget the professional aspect of training, and that the activity would really become a normal process of personnel development which takes into account all the experience a man receives in his practical work within the company. To make the point quite clear, I will restate it in this way: that when one talks about the subject of training, one

has to take into careful consideration the experience that a man gets on the job, and that the more formal training activities should be regarded as an adjunct to that experience, and must be used as a carefully-planned aid to general development on the job. In that sense, it does become technically interwoven into the personnel development policy of a company.

The next point arises from the observations just made. In the analysis of the ways in which training can be done I would have preferred: (1) on the job; (2) off the job but done locally; and (3) off the job and done centrally. In regard to (1), 95 per cent, if not more, of a man's time will be on the job, and it is the real influence of that situation that is going to hinder or help his development.

Secondly, "off the job but done locally." As an illustration, one can refer to apprentice training schools, which have been developed widely within industry in the last ten years, and have now become a feature of the development of apprentice training in my own company. There are now quite a large number of these apprentice basic training schools away from the job, which provide a carefully-planned training in the first year of apprenticeship under selected and trained instructors.

Thirdly, "off the job and done centrally," which applies to large industrial organizations. In my own company there is a staff training centre, where we are able to run some of the courses to which Mr Butler and Mr Debenham have referred. These courses serve a purpose for the company as a whole and would not be well placed or appropriately run were they organized locally or divisionally. It is, of course, dangerous to try to suggest that these three ways provide alternatives. The authors have emphasized the need to keep all these various methods in mind and then to decide which method is most appropriate for any particular set of circumstances.

Another general point I would like to make is this: I do feel that one of the heaviest responsibilities that rests upon those concerned with training in industry is judging the extent and kind of training that we may advise or arrange for any particular individual to undertake. I believe that we can go very wrong in encouraging individuals to undertake ambitious education and training schemes that may lead them to think that they are capable of doing something much more than they have the potentiality to tackle. This may seem a very extraordinary statement by an education officer, but I do feel that those of us who have the task of advising, particularly young people, on the sort of courses, both inside and outside, that they should pursue in order to progress, carry a serious responsibility for seeing that what we advise is adjusted to an individual's potentiality. To be responsible for a number of young people struggling to get external degrees at London University, when clearly their *métier* is something rather less ambitious, is a serious matter which can lead to considerable frustration. Although this point has not been mentioned, its importance should be stressed. On the other side of the coin, we must not overlook the fact that we are equally concerned with the provision of opportunities that will enable people to make the best of their abilities.

These three papers provide a sound basis of approach to the subject, and if there is any note of caution to be sounded, it is as Abraham Lincoln once said, "You cannot help a man permanently by doing for him what he should do for himself."

T. L. Stephens: I should like to refer to the statements made by Mr Perkins on the question of "on the job" training, and the position of the training centre in relation to it. It is a matter of how training centres should be used; one has come so often in contact with a situation where an apprentice has spent some time in the training centre and then goes on to the job, where he meets with the comment that he can forget all he has learnt at the training centre and start afresh in the right way. Conversely, I can recall occasions where well trained young apprentices, after their initial period at the training centre, found themselves on mediocre and quite unsuitable work, with resulting frustration. In these instances the two aspects of training were not properly integrated. It seems to me that the training centre does have its place in the organization, but it should be appropriate to the training need and in correct relation to "on the job" training. It is also important that the people who are responsible for the instruction and training in the training centre are "of the job" and "of the works," not something apart, as Mr Perkins commented, and not training specialists, who deal in jargon and theories.

D. Morten: We have listened to three papers, prepared with, I can only think of the word "collusion," although it is not a very nice word. Three very good papers, all bearing the mark of experience rather than theory. That is not strange, because this is the oil industry, which, by the nature of things, has had to go in for training for a very long time. It may be more formal now; many years ago I do not think the big companies had training departments, but that does not mean that they did not do any training.

What is interesting is that such a very large number of other companies, and a very large number of articles appearing in the technical press, stress this whole question of training, accompanied by the need for career planning.

There are two points that I personally regard as important. The first is that the official training officer should not be the man who does the actual training; he has plenty to do in seeing that it is co-ordinated. He will certainly have something to do with it himself but it is training on the job by the line people that is so vital.

The second point is that the people who do the training must be closely associated with and experienced in the industry and must not withdraw themselves into some slick academic shell where they can live on a soup of jargon and pedagogy, because this always causes a certain amount of trouble.

There is another point, which has probably got nothing to do with the papers, although in Mr Debenham's paper the word "education" was mentioned: I should regret very much if the petroleum industry got outside its own bailiwick in the educational and training fields and that, as a result, we should have to engage a lot of little B. Pets. from the universities. We would do well to stick to those who are educated in the humanities and sciences and not go down the technical line farther than the four primary technologies.

A. I. S. Debenham: The word "education" was included, because it seemed to me that career development, which was one of the things that we were looking at in this symposium, is the increase in stature of a man, not only in pure technical information, but what I would call education, the rather broader development of a man, and that the techniques that I was talking about were still applicable.

R. S. Butler: I think, by and large, it is the experience of many of those concerned in training that instructional staff, or specialists developing training schemes from Head Offices, are often drawn from operat-

ing departments, and quite often return from training posts to operating departments. Conversely, training staff recruited directly from outside are given experience in operating departments at an early stage and return to their training work with first-hand experience. I do not think it is our experience that training staff live in ivory towers away from the dusty arena.

R. W. J. Smith: I was very interested to hear Mr Stephens' comments on apprenticeship training, particularly when he mentioned the length of time which in this country is traditionally devoted to it. I was equally interested to hear that in Germany they were training apprentices very successfully on a three-year basis. There is, I think, one word of caution needed here. Reference was made by Mr Stephens to the war-time arrangements whereby, in agreement with the trades unions, there was a relaxation of apprenticeship agreements and craftsmen were trained in as short a time as one year. We should remember that the craftsmen produced in this way were, as was intended, of a very specialized nature; the country as a whole produced very good radar mechanics, instrument mechanics, motor fitters, etc., all of whom were skilled in a very narrow field. I do suggest that the oil industry needs good all-round craftsmen trained to do all the jobs required in their craft. This need must, I suggest, be borne in mind when considering a shorter apprenticeship period, but I would fully agree that such training should be possible in three years.

We all have the responsiblity for the training of the new technical graduate when he joins the industry, and it must be remembered that these young men have spent three and even four years at a university and possibly two years in the Forces and they are desperately anxious to do a responsible job of work. I suggest that we must avoid any formalized training schedule for these young men and should look at each individually, treat him as an individual, and train him accordingly. The training schemes must therefore be completely flexible to meet this requirement, and it is the training officer's job to study each man individually and make suitable recommendations so that his training is reduced to the minimum necessary to enable him to do a responsible job.

One point has not been mentioned by any of the speakers; I would like to know the general views on the use of management courses which are operated outside any particular industry. I have in mind, for example, the Henley Staff College. I would suggest there is definite advantage in using these courses, particularly for staff at higher levels, since they give them the opportunity of meeting people from other industries and discussing with them the many problems of management which are frequently common to all.

Lastly, I would like to support Mr Perkins when he mentioned the serious responsibility involved when advising boys in regard to part-time study and how important it is to avoid encouraging a boy to aim at a technological qualification for which he is not really capable. There is nothing more tragic than encouraging a boy to take such a qualification when there may well be serious doubts as to whether he is really capable of using his knowledge as a qualified technologist in industry.

T. L. Stephens: On the question of craft apprenticeship, whilst agreeing that there is scope for reviewing the period of apprenticeship, I would also like to add that there are one or two other aspects of craft apprenticeship which must be considered. First, the relaxation of the starting age. Instead of making it round about sixteen, as it already is, it should be increased, thus providing more flexibility, so that people who come to industry, particularly those who have completed their National Service, still have a chance of becoming good craftsmen. After all, there may be late developers who have the ability to become good craftsmen.

Secondly, there is the question of the standard of craftsmanship in the industry. I suggest some form of practical test on concluding the apprenticeship which applies thoughout the industry and could possibly be put on a national basis.

On the question of graduate training, particularly for the post-National Serviceman, we would like to see that their formal training is carried out as quickly and efficiently as possible, so that they can get down to the job for which they are best suited, taking as much responsibility as possible. There is nothing more frustrating for a young man who has done his National Service, and very likely has taken his commission, to come back and be put on to some form of highly-organized and lengthy training programme.

On the question of the educational side, and advice on further eduation, there is for the training officer a very real responsibility, and a field that has yet to be developed. There are a large number of young people who do participate in further education, and it is our particular duty on the training side to go carefully into these cases, to make sure that their further education requirements are met, and that they are following the appropriate course and that it is one they are able to complete. This must be dealt with on an individual basis.

A. F. J. Lee: I was interested to read that a course of teaching technique is given in one week. We find that we need three weeks as a minimum, and even then it is feared that the course is insufficient and, in some respects, inadequate.

It sounds a little too simple when the training side says that it explains the need for training to management and then it gets the staff and money to do it. I do not think it is as easy as is suggested. This may explain the instructor training course. To underline the need for expert instructors, I can instance two schools that taught the same skill: one took 10½ hours and another 110 hours to reach the same standard. It is one of our disadvantages that we are not often able to measure the success of our training, but I am afraid that when we can we are apt to get results of that sort, and this probably applies in areas where we are unable to measure. The one-week instructor course may have been used to get away with it with management, but I must stress the need for investment in efficient instructors and say that I think three weeks is a minimum.

In regard to the division "Discussion Groups" and discussion group leading. The difficulty in using a broad heading to cover a number of techniques is realized, but I would like to make one point on the Harvard case study method. It is suggested that it is important that the instructor should know what points are to be made by the study of the case. May I suggest that the whole point of the Harvard case method is that the leader is not an instructor; he does not lead and, in point of fact, fails in so far as he does lead. Here I might refer to the books in which the handling of the cases has been documented in detail and which show the care with which the exponents of this method avoid leading and resist pressure from the group that they shall be led. The treatment has much in common with the medical use of role-playing. This subject is also closely bound up with one of the most difficult jobs of all—that of assessing

the actual training needs of individuals. It is one that tends to be glossed over.

One last point on the question of education as against training. I see them as synonymous. They must be synonymous if one is going to expect promotion from the bottom to the top, because there is a stage when it is difficult, if not impossible, to turn a technician into a manager.

A. I. S. Debenham: We do not expect to produce a teacher in a week. We do have a week's course on these techniques of training, but it is designed for the many people in our own company who have to talk about their subject to other people. It is designed merely to present these techniques to these people and to give them an opportunity of trying them out on one another.

We also run a 7–8-week course for overseas personnel which includes these principles, the presentation of this short course, and other training matters. These men will go away to some distant part of the world and be responsible for the training in their particular company. We do not feel that a teacher can be produced in a week, but it is surprising what some people can pick up in this time. Others do not get so much, but we do the best we can for them.

I was expecting that someone would bring up the question of using cases, because for many years Harvard has been using what one might perhaps call the *laissez-faire* method of taking a case. Although I have not been to Harvard, I have seen one of their professors in action, and there is no doubt that results come from this method, although it requires a certain amount of time to produce them. It is also necessary for quite a number of cases to be discussed by the group, who remain together for a length of time for this purpose and who go through various stages of frustration, irritation, and so on until they begin to get something from it by themselves. I feel that one can certainly get great value from handling case studies in this way and Harvard has done so. However, if one has only a week's course, or an opportunity of taking and discussing, say, ten cases with a group of people, then the time is not sufficient for these people to obtain the self-discipline and self-education which they will get from a longer period of knocking one another about. Therefore the instructor has a role here, not so much to say, "This is the sort of problem this case sets out, and you discuss it," but to check the group member's understanding of the situation, and, by suitable questions, to get that man and the others in the group to think about the principles involved. It is quite possible that a man may make a statement which is not correct, or is using as a fact something which is only an opinion in the case. Sooner or later, if one left it going on long enough, someone would get up and say, "That is all nonsense; it does not say that." With a question from the instructor leading the case, however, that process can perhaps be accelerated, and more value can be obtained from the case in the time available. I believe that certain members of the Faculty at Harvard do now feel that more can be done by the instructor taking some sort of a part. Not necessarily saying, "This is what is in it; here is the answer," but by forcing the man to understand what he himself is saying.

R. S. Butler: With reference to the point about the length of time that is necessary to train a man in discussion-leading or in lecturing, I do think it is important to introduce training or to develop training within a company at the pace, or with the degree of sophistication, that the company can tolerate. It may well be that it is better to start an activity in a way which one as a specialist recognizes as falling short of one's standards, as a means of gaining acceptance and of experiencing some of the teething troubles, thereby at a later stage permitting oneself to obtain support for a more extensive and effective treatment.

Recently, for a department which provides many lecturers for company courses, we arranged a short morning exercise in London on the use of visual aids. It became apparent that there was more to it than we had covered, and that there was a parallel training need on lecturing techniques. From that, what is probably an all too short course—it takes about three days—now has the active support of the departments which first asked only for a morning course.

In regard to the question of the technician specialist who becomes too old to become a manager, it does depend on the individual case. It does happen that specialists become supervisors, in a small way, of other specialists at quite an early stage of their career with the company. I would suggest there is not a sudden leap from specialist to manager or general manager, but a gradation from specialist through group leader and section head, to manager of a laboratory, perhaps, or research division, and so on to general management. Those who have the personality characteristics and the willingness to carry responsibility will immediately commend themselves to this route at quite an early age. Those who, for various reasons, are not suited to that will probably remain specialists, and perhaps at a later age in life it would be a mistake in those cases to attempt a development. Our problem should not be that of attempting to convert the specialist of many years service into a manager, but rather making sure that we bring in as many as we can in the early stages to this stage-by-stage growth in management functions.

C. P. Williamson: I have great sympathy with the people who are in the training department, because they alternate between being confounded nuisances to the people for whom they are giving the training, that is the operating departments, and being a godsend, because they can absolve those departments from doing the work. The truth lies somewhere in between. The point I want to make is that all our training should be in gradation, and that it should be bringing out in people, in their own particular lines, full, rounded personalities. From that point of view, I would like to suggest that the higher the training goes, the more necessity is there for that training to be in two parts. One part as their training affects the company, and the other part as their training affects their personality. That leads me to suggest that there is a great deal of room for altering it to the sandwich idea, as we are getting in apprenticeships, where the youths who are going on to these sandwich courses are doing time at work and time outside the works in different environments. Having been on a residential course outside industry, I found great benefit from mixing with similar types of people in other industries. It made me realize that there were industries other than the oil industry—it was quite a surprise. It made me realize also that their problems are not unlike the problems that we have. I found out, moreover, that they dealt with some of their problems much better than we do inside the oil industry. So my plea would be that whilst recognizing the need for formalized company training, one should not lose sight of the fact that it is a good thing for people to mix outside, and it is wise to give people a little education in things other than their mere jobs. Then perhaps we can avoid this dreadful position of technicians not being good enough for managers.

F. V. Pedrick: Although I am not connected with staff training, I am one of those responsible for dealing with the raw material coming into an oil company and have to explain the mysteries of the oil industry to them. May I ask all staff training officers not to over-emphasize the prospects of promotion, because we know in our hearts that out of every ten, only two have a real chance of promotion, and therefore we have to deal with the other eight discontented workers later on.

A. I. S. Debenham: In answer to the point about the use of outside courses in management training, I would say straight away, "Yes, there is a lot of good value in outside management training courses." We certainly use outside courses of all sorts; on the other hand, there are certain aspects of company information which can only be given on inside courses. In addition, the number of places available on suitable outside courses is sometimes not sufficient to supply the need. So one has to compromise, and in fact, in our own Management Study Group, we try to do something on these lines by inviting people from outside industry in order to bring a wide industrial background to the discussions.

F. H. Perkins: Mr Butler's paper has raised the question of the use of formal training courses for assessment purposes. His observation is that we should at all costs avoid any attempt at assessment of personal possibilities for promotion by a man's performance on a formal course.

Those of us who are concerned with running the more typical formal training courses are in an advantageous position in making certain assessments. In fact, in my own experience these assessments have corresponded very closely with those made by men more directly concerned with an individual's work. It has been impressed on me by senior members of the company that we could make very much more use of our assessments in giving guidance on people's potentialities, which might otherwise remain undisclosed. The real dangers have been highlighted by Mr Butler, and the running of a course where men attending it feel that they are under assessment is not an enviable task. The whole success of a course depends on everybody feeling they are in an environment where they can be true to themselves and give of their best.

On the other hand, there are ways, perhaps more subtle in character, of passing on some of the impressions that have been gathered. I should mention that we do not do it in my company as a matter of routine, but if the manager of a man who has attended one of these courses wishes to consult us at any time about the impressions that we have gained, then we are prepared to discuss them with him. This has been found very helpful on occasions. We are very careful in such situations to preface our remarks by saying, "These are our impressions based on a short experience on a formal training course." I have found that this approach has been well received, and has not led to any serious difficulty when it has been taken into account.

R. S. Butler: I do not find myself in a great measure of agreement with Mr Perkins on this point, and perhaps I can point out some of the considerations that I think apply. First of all, one must not look at this question of the training course as an assessable situation in isolation. It must be regarded in the context of the company's regular personnel policy on assessment. The situation is quite different in a company which has no regular staff performance review or annual appraisal system than in a company which does have one. I was recently speaking with an executive of a company which runs a residential staff college, and which does not have any established procedure of annual assessment. He was appalled at the prospect of being requested to give reports on people and their performance on these courses, and the undue weight which would be given to these judgments in the absence of any more comprehensive, and perhaps more objective and equitable judgment based on the year's work. Even when one does have such a system, I still would not wish to see anything more than an occasional enquiry from a manager concerning performance on a course. However much one can form what one considers to be a valid judgment of an individual's performance, very little is known of his motivation during that course, or of the stresses that he might have been under, and I suspect that if much more was known about those two things, one's judgment might well be different. Again, people, by one analysis, are mainly extrovert or introvert or somewhere in between—one can take other broad forms of division, but whatever personality structure one uses to compare people, their performance on courses will differ on account of that. The evidence of their behaviour can be misinterpreted in the absence of knowledge of their personality structure, to their advantage or to their disadvantage.

Finally, however much one prefaces an assessment with "This is based on a short observation," I still think it has the same effect as a newspaper headline or a misreporting of information which is duly corrected later in a little paragraph on the back page. It never undoes the harm that has been done by the prominence which was given on the front page.

A. I. S. Debenham: It is worth stressing that the selection for training courses, which normally rests with the line people, is an extraordinarily important thing. Clearly if one sends a man to a course and he is not suited for it, not only is it wasting his time, but one may also be upsetting the course as well.

Lord Geddes: This has been an extremely interesting discussion, and I am sure you would wish me on your behalf to thank the authors for the way in which the papers were prepared and presented and for the subsequent handling of the discussion.

The meeting then closed with a warm vote of thanks to the three authors.

THE RELATION BETWEEN REDWOOD NO. I SECONDS AND KINEMATIC VISCOSITIES *

By MASUMI KINOSHITA †

SUMMARY

The relation between Redwood seconds and kinematic viscosities has been studied, comparing the experimental data obtained on four conventional Redwood No. I viscometers and on a set comprising five suspended-level master viscometers with long capillary tubes of different diameter. 27 oil samples of suitable viscosities covering the range 2–200 cS at temperatures between 30° and 100° C were used. Statistical analysis of the experimental data and derived values indicated that a function $\log\log\{A/(A - \nu/R\}$ has a linear relation to $\log\nu$, as in the following equation

$$\log\log\{A/(A - \nu/R)\} = \log k + n\log\nu$$

where R and ν are Redwood seconds and kinematic viscosities respectively, A is a value of ν/R in the viscosity range greater than about 70 cS, and k and n are constants independent of both temperature and correction factors of Redwood viscometers. Furthermore, it was indicated that the reciprocal value of A, or $1/A$, shows a linear relation to temperature t, as in the following equation

$$1/A = a_0 + a_1 t$$

where, a_0 and a_1 are constants.

Research work published by other investigators, such as G. Barr and F. H. Garner *et al*, is also discussed, together with experimental results by the author. It can be emphasized that, as the result of this investigation, the following empirical equation, which is obtained by combining the above two equations, can be used successfully for the conversion of kinematic viscosities to Redwood No. I seconds in the whole viscosity range greater than about 3 cS (about 34 Redwood sec) at the temperatures between 20° and 100° C approximately.

$$R = (4{\cdot}048 + 0{\cdot}00062t)\nu/(1 - 10^{-0{\cdot}06668\,\nu^{0{\cdot}6795}})$$

where R and ν are Redwood No. I seconds and kinematic viscosities in cS respectively, and t is temperature, ° C.

Furthermore, it was found that Ubbelohde's conversion table, which is currently used for the conversion of kinematic viscosities to Redwood No. I seconds, possibly represents the relation between kinematic viscosities and Redwood seconds obtainable in the Redwood viscometer No. 1307, which is authorized as the standard by the Institute of Petroleum, with a deviation of about 0·5 per cent; however, the table does not represent with certainty the relation obtainable in other Redwood viscometers, such as No. 3967 and other commercial instruments used by the investigators mentioned above, as well as by the author. The Redwood seconds obtained by conversion from kinematic viscosities by means of the above-mentioned table show a characteristic deviation from the values observed in the Redwood instrument at the range of about 30–120 sec (2–30 cS), and the deviation reaches a maximum amounting to as much as 3 per cent or more in the limited range of about 40–60 sec (6–12 cS).

Moreover, it can be deduced from the data of Barr's experiments that the standard viscometer No. 1307 has some difference in character compared with the No. 3967 instrument or other commercial Redwood viscometers.

INTRODUCTION

THE relation between Redwood seconds and kinematic viscosities was studied experimentally and theoretically by various investigators, especially by the members of the Viscosity Panel of the Institute of Petroleum, such as Higgins, Barr, and Garner *et al*. In 1913, Higgins [1] first proposed an equation for the conversion of Redwood seconds to kinematic viscosities by comparing the data obtained in a Redwood viscometer and in an absolute viscometer for eight oils at various temperatures between 10° and 60° C. His equation was revised by Barr [2] in 1936, after detailed research work arranged by the Viscosity Panel. The study was carried out with 12 oils at a temperature of 70° F by using three U-tube viscometers and the Redwood viscometer No. 1307, which was used by Higgins in deriving his equation and has been adopted as a standard of reference by the Institute of Petroleum. In the same year, Garner, Broom, and Taylor [3] also studied the relation between Redwood seconds and kinematic viscosities at temperatures of 70°, 140°, and 200° F by using a Redwood viscometer No. 3967 and U-tube viscometers. As the result of those investigations, the following three equations of same type (1) for the temperatures of 70°, 140°, and 200° F respectively were deduced for the relation between kinematic viscosities ν in cS and Redwood seconds T obtainable in the standard Redwood viscometer No. 1307

$$\left.\begin{aligned}
&\text{At } 70^\circ\text{ F}\quad \nu = \frac{T}{10} \times 2{\cdot}47^{\left(1-\frac{39{,}720}{T^{2\cdot015}}\right)}\\
&\text{At } 140^\circ\text{ F}\ \nu = \frac{T}{10} \times 2{\cdot}45^{\left(1-\frac{81{,}190}{T^{2\cdot193}}\right)}\\
&\text{At } 200^\circ\text{ F}\ \nu = \frac{T}{10} \times 2{\cdot}415^{\left(1-\frac{97{,}960}{T^{2\cdot2994}}\right)}
\end{aligned}\right\}. \quad (1)$$

On the basis of the formulæ (1), the Viscosity Panel compiled a viscosity conversion table in 1936.[4] This is the currently-used IP viscosity conversion table,[5] which is the basis of the conversion tables developed

* MS received 26 June 1956.

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by Ubbelohde [6] and Inaba.[7] These tables were accepted for many years without serious question.

In 1952 the author [8] found, from experimental work undertaken with the object of determining correction factors of nine commercial Redwood viscometers and seven Saybolt Universal viscometers, that the Redwood seconds obtained by conversion from kinematic viscosities by means of the above-mentioned conversion table showed a characteristic deviation from the values observed in the Redwood viscometers at the viscosity range of about 30–140 Redwood sec (about 2–35 cS), and the deviation had a maximum value amounting to as much as 3 per cent or more at about 40 Redwood sec (about 6 cS).

The author therefore arranged a research programme with the purpose not only of re-examining the fact mentioned above, but also with the object of studying the relation between Redwood seconds and kinematic viscosities.

In order to ensure the accuracy of experimental results, the determination of Redwood seconds was made with four Redwood viscometers of British manufacture made in 1951, while kinematic viscosities were determined with a set comprising five suspended-level master viscometers with long capillary tubes of different diameters. A series of 27 oils of suitable viscosities varying from 2 to 200 cS at temperatures of 30°, 50°, 80°, and 100° C was used.

The experimental data and derived values were treated statistically and, from the result, it was possible to deduce a quite satisfactory experimental formula. The author therefore investigated the co-ordinative research data, which were published by the above investigators such as Barr and Garner *et al*, together with the experimental results obtained by the present author. As the result of this investigation, a formula, which is suitable for the conversion of kinematic viscosities to Redwood No. I seconds at any temperature, was deduced. On the basis of the formula, a new conversion table for the kinematic viscosity conversions at various temperatures was compiled to take the place of the above-mentioned tables.

Since the primary standard of viscosity, *i.e.* the viscosity value of pure water at 20° C, was revised on 1 July 1953, and the new value of 1·0038 cS [9] has been widely adopted in place of the old value of 1·0068 cS, the kinematic viscosities indicated in this report are based upon the new value, and the kinematic viscosities taken from other references are also corrected.

METHOD OF VISCOSITY MEASUREMENT AND THE RESULTS

In accordance with this programme, mineral oils with viscosities varying from about 2 to 200 cS (about 30–800 Redwood sec) in the temperature range 30°–100° C were submitted to the four designated laboratories for Redwood viscosity determination. The kinematic viscosity of each sample was determined by the author at the same temperatures, 30°, 50°, 80°, and 100° C, as the Redwood viscosity determination.

Four Redwood No. I viscometers, Nos. 5122, 5187, 5224, and 5225, made by Baird and Tatlock (London) Ltd. in 1951 were employed. The manufacturer's accuracy certificate indicated 0·5 per cent slow for No. 5122 and 0·25 per cent fast for No. 5225; the accuracies of the other two viscometers are unknown. The thermometers used for measuring Redwood seconds were preliminarily calibrated against the thermometer No. 126-T52 with the certificate of Eichdirektion Berlin dated January 1953, which was used for the determination of kinematic viscosities in this work. Stop watches accurate to within 1 sec/hour (about 0·03 per cent) were employed in all experiments, both on the Redwood and the kinematic viscosity.

A skilled and experienced technician in each of four laboratories undertook the measurements of Redwood seconds on all samples. Redwood viscosities were run at least twice, but usually three or five times, on each oil, and the mean values were recorded. Other details of procedure for measuring Redwood seconds were in accordance with IP 70/53.

Kinematic viscosities were determined on a set comprising five suspended-level master viscometers with long capillary tubes of different diameters. The master viscometers were all made of hard glass and were almost identical in construction with the suspended-level master viscometer recommended by the Viscosity Panel of the Institute of Petroleum in 1952,[10] the only difference being that the capillary tube was 50 cm in length, 10 cm longer than that of the IP. A thermostat with double compartments, namely, an inner and outer bath, was used, in which the temperatures of both compartments could be controlled automatically. The temperature of the internal bath immersing the master viscometers was always kept constant to 0·001° C. The master viscometer with the smallest bore was calibrated with pure water at 20° C as the primary standard, the accepted value of the viscosity of water being 1·0038 cS at the temperature; the time of flow of 2·06 cc of water was determined to be 612·2 $\pm$ 0·4 sec in the smallest viscometer. The other four master viscometers of larger bore were calibrated by the stepping-up method,[10, 11] using mineral oils of suitable viscosities. After calibration of the master viscometers, the viscosity values of the API viscosity oil standards, Alpha, Beta, and Gamma were measured. These results varied at most only by 0·1 per cent from the API values given in the certificate attached to the specimens dated August or November 1953.

The results of viscosity measurements are set out in Table I, which includes also the derived values of ν/R and of $\log \log \{A/(A - \nu/R)\}$ calculated from them for the purpose of plotting in a graph. The probable

error in the measured values of kinematic viscosities was about 0·1 per cent or less and very rarely exceeded 0·2 per cent. The reproducibility of measured values of Redwood seconds in terms of standard deviations already recognized by other investigators.[1-3] It is also apparent from the values in Table I that the converging value A has a tendency to decrease with increments in temperature t.

TABLE I

Experimental Data and Derived Values and Deviation of Converted from Experimental Redwood Results

Sample	t (° C) Temperature	ν (cS) Experimental kinematic viscosities	R (sec) Experimental Redwood No. I seconds					Redwood seconds by conversion of kinematic (sec)		δ (%) Relative percentage deviation converted from experimental values		ν/R	$\log\log\left(\frac{A}{A-\frac{\nu}{R}}\right)$
			Laboratory 1 No. 5122	Laboratory 2 No. 5187	Laboratory 3 No. 5224	Laboratory 4 No. 5225	Average	By Ubbelohde conversion table	By new empirical equation	By Ubbelohde conversion table	By new empirical equation		
A	30	6·147	42·2	42·1	42·25	42·2	42·2	41·07	42·28	−3·5	−0·7	0·1457	−0·4156
B	30	10·22	53·8	53·2	54·2	53·8	53·8	52·52	54·05	−3·2	−0·4	0·1900	−0·2007
C	30	17·18	76·4	76·0	76·5	76·7	76·4	75·47	76·66	−2·0	−0·6	0·2249	0·0117
E	30	82·81	336·5	331·9	333·3	335·0	334·2	336·5	336·5	−0·1	−0·2	0·2478	—
F	30	99·62	404·4	399·4	402·4	401·6	402·0	404·9	405·2	−0·1	−0·1	0·2478	—
G	30	111·5	452·6	447·1	446·9	449·6	449·1	453·1	453·0	0·1	0	0·2483	—
A	50	3·661	35·5	35·5	35·4	35·4	35·5	35·85	35·75	0·2	−0·2	0·1031	−0·6305
B	50	5·452	40·4	40·8	40·2	40·3	40·4	39·58	40·51	−2·8	−0·6	0·1350	−0·4652
D	50	18·86	82·6	82·8	82·3	81·9	82·4	81·59	82·76	−1·8	−0·5	0·2289	0·0516
E	50	32·31	132·9	131·8	132·9	132·5	132·5	133·4	133·3	−0·1	−0·3	0·2438	0·2641
G	50	42·13	172·4	170·3	171·1	171·1	171·2	172·8	172·3	0·1	−0·3	0·2461	0·3578
H	50	58·46	237·0	235·6	235·8	235·3	235·9	239·0	238·5	0·5	0·2	0·2478	—
I	50	113·3	455·9	456·1	463·6	454·1	457·4	459·7	462·0	−0·3	0·1	0·2477	—
J	50	137·5	559·4	550·2	561·0	552·1	555·7	560·7	560·7	0·1	0	0·2474	—
B	80	2·798	33·0	33·0	33·25	33·0	33·1	33·14	33·63	−0·7	0·7	0·0845	−0·7388
D	80	7·623	46·6	46·6	46·7	46·6	46·6	45·70	46·77	−2·7	−0·5	0·1636	−0·3243
H	80	18·55	81·6	81·6	81·6	81·9	81·7	81·18	82·01	−1·2	−0·5	0·2271	0·0446
K	80	76·70	310·8	309·0	312·0	308·4	310·1	317·6	314·1	1·6	0·4	0·2473	—
L	80	84·77	345·1	345·8	343·6	340·9	343·9	351·1	347·3	1·3	0·1	0·2465	—
M	80	94·94	387·8	387·9	386·2	382·9	386·2	393·0	388·9	1·0	−0·2	0·2458	—
C	100	2·745	32·9	33·2	33·15	33·1	33·1	33·09	33·60	−0·8	0·6	0·0829	−0·7476
D	100	4·884	—	39·0	39·15	39·2	39·1	38·72	39·26	−1·8	−0·5	0·1249	−0·5107
G	100	8·782	50·1	50·1	—	50·1	50·1	49·23	50·27	−2·5	−0·6	0·1753	−0·2650
J	100	20·46	89·0	88·3	89·3	88·0	88·7	89·16	89·11	−0·3	−0·4	0·2307	0·0853
N	100	139·2	577·0	559·1	575·0	554·7	566·5	584·2	572·2	2·3	0·1	0·2457	—
P	100	150·2	629·6	601·1	623·1	600·8	613·7	631·3	617·4	2·1	−0·3	0·2447	—
Q	100	172·1	716·7	683·1	719·5	682·2	700·4	723·1	706·7	2·4	0	0·2457	—
							Standard deviation (%) =			1·73	0·41		

indicated a maximum of 1·0 per cent with the exception of 2–2·9 per cent for three samples, N, P, and Q, the overall average being 0·69 per cent.

DERIVATION OF EMPIRICAL EQUATION

By plotting the values of ν/R in Table I against ν, a continuous and smooth curve can be drawn through them, and the curve indicates that the value of ν/R increases gradually with increments in ν and finally approaches to a constant value A in the viscosity range greater than approximately 70 cS (about 300 Redwood sec). This characteristic has been

As a result of detailed study of this data, it has been found that the relation between Redwood seconds R and kinematic viscosity ν can be represented by the equation

$$R = \nu/\{A(1 - 10^{-k\nu^n})\} \quad . \quad . \quad . \quad (2)$$

where k and n are constants.

This equation can be rewritten in a linear form

$$\log\log\{A/(A - \nu/R)\} = \log k + n \log \nu \quad . \quad (3)$$

In other words, by plotting $\log\log\{A/(A - \nu/R)\}$ against $\log \nu$ there a straight line should be obtained from the above equation, from which the values of k and n can be ascertained.

On the other hand, the relation between A and t was represented by a polynomial equation

$$1/A = a_0 + a_1 t + a_2 t^2 + \ldots . \quad . \quad (4)$$

where a_0, a_1, a_2, . . . are constants.

The values of constants and the order of equation (4) were determined from the experimental values as follows.

In order to determine the equation (4) statistically, the values of ν/R in the viscosity range greater than 70 cS were extracted from Table I and their reciprocals R/ν, *i.e.* the values of $1/A$, were arranged according to temperature and viscosity as given in Table II. When the values in Table II are treated by the common method [12] are calculated, the following results are given

$$\left.\begin{aligned} a_0 &= 4{\cdot}011 \pm 0{\cdot}018 \\ a_1 &= 0{\cdot}00061 \pm 0{\cdot}00031 \\ a_2 = a_3 &= \ldots = 0 . \end{aligned}\right\} \quad . \quad . \quad (5)$$

From these values (5), the equation (4) becomes

$$1/A = 4{\cdot}011 \pm 0{\cdot}00061t \quad . \quad . \quad (6)$$

The values of $1/A$ and A calculated by the equation (6) are shown in Table II, and the deviation of these values from the average experimental values is smaller than 0·1 per cent.

In order to test the equation (3), the values of log log $\{A/(A - \nu/R)\}$ were calculated from the values of ν/R in Table I and of A in Table II as set out in Table I. These values are plotted against log ν in Fig 1, in

TABLE II

Experimental Values of (1/A) *at Various Temperatures*

t (° C)	$(1/A)$					A
	1	2	3	Average	Calculated values †	Calculated values †
30	4·036	4·036	4·028	4·033	4·029	0·2482
50	4·035 *	4·037	4·041	4·039	4·042	0·2474
80	4·043	4·057	4·068	4·056	4·060	0·2463
100	4·070	4·086	4·070	4·075	4·072	0·2456

* Omitted (ν = 58·46 cS).
† Calculated by equation $1/A = 4{\cdot}011 + 0{\cdot}00061t$.

TABLE III

Analysis of Variance of the Data in Table II

Source of variation	Sum of squares (s.s.)	Degrees of freedom (d.f.)	Mean square (m.s.)	F
Viscosities .	129·5	2	64·75	0·94
Temperature :				
Linear . .	3192·3	1	3192·3	46·51 *
Residue . .	161·4	2	80·7	1·18
Error . .	411·8	6	68·63	—
Total . .	3895·0	11		

* Denotes significance at the 1% level.

mon method of analysis of variance [12] by taking both temperature and viscosity as the sources of variation, results are given as shown in Table III. As the result of this analysis, the author arrived at two conclusions :

(1) The value of $1/A$ does not vary with the change in ν and is constant in the viscosity range greater than 70 cS.

(2) Although the value of $1/A$ does vary with the change in t, the variation is in accordance with the first order of t and is negligible for the second order or more.

Now, if the 99 per cent confidence limits on the values of the constants in equation (4) by the common

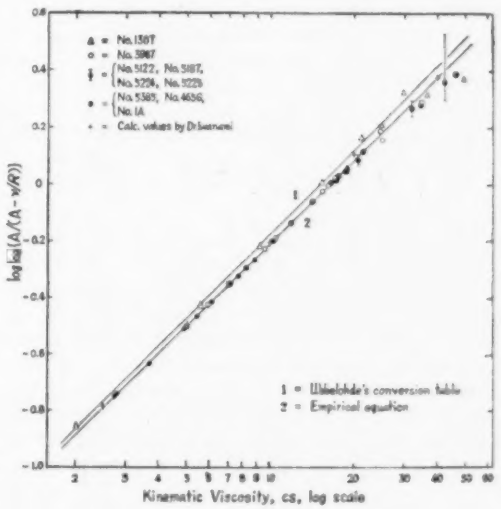

FIG 1

which the standard deviation in log log $\{A/(A - \nu/R)\}$ calculated from the standard deviation in the measured value R is also shown. It is obvious that the linear relation exists clearly between log log $\{A/(A - \nu/R)\}$ and log ν, and in addition the straight line in Fig 1 is independent of both temperature and correction factor of the viscometer. Consequently, the author arrives at the conclusion that the two constants k and n, which represent a straight line in Fig 1, are independent of both the temperature and of the correction factor of the Redwood viscometer. On the other hand, it is also apparent that the constant A is not only a function of temperature, as ascertained above, but that it also includes the correction factor of the Redwood viscometer. It is further noted from Fig 1 that the standard deviation in log log $\{A/(A - \nu/R)\}$ is magnified in the viscosity range more than about 30 cS and, as a consequence, the difficulty in determining accurate values of the constants k and n becomes

apparent in this viscosity range. Therefore the author, with the object of establishing the equation (1) as a general formula, has determined the values of A, k, and n by full utilization of the characteristics noted above and consideration of research data obtained by other investigators as well as by the author.

The research data quoted here refer to the experimental works done by Barr,[2] Garner, Broom, and Taylor,[3] to work by T. Nagano and M. Oguma carried out in 1955 under the auspices of the Sub-committee on Viscosity Measurement of the Japanese Industrial Standards Committee (research results are unpublished but are presented in Table IV by courtesy of T. Nagano), and to the theoretical research work by S. Iwanami [13] based on the viewpoint of hydrodynamics.

In the experimental work by Garner *et al*, all the Redwood measurements were obtained with the receiving flask insulated, while in IP 70/53 no insulation is used at any temperature. Since it was indicated, in their report, that the effect of insulation was clearly apparent only at a temperature of 200° F and that the effect was negligible at other temperatures of both 70° and 140° F, their data obtained at 70° and 140° F were used for reference in this work. The experiments made by Nagano and Oguma were performed at the temperatures of 30° C, 50° C, and 200° F. Of the three Redwood No. I viscometers used in their experiments, viscometers No. 4656 and No. 5385 were of British manufacture, of which the latter was certified in detail by the National Physical Laboratory. The third viscometer, No. 1A, was of Japanese manufacture.

TABLE IV

Experimental Data by T. Nagano and M. Oguma

Temperature	ν (cS) Experimental kinematic viscosities	R (sec) Experimental Redwood No. I seconds				Redwood seconds by conversion of kinematic (sec)		δ (%) Relative percentage deviation of converted from experimental values		$\log\log\left(\frac{A}{A-\frac{\nu}{R}}\right)$
		No. 4656	No. 5385	No. 1A	Average	By Ubbelohde conversion table	By empirical equation	By Ubbelohde conversion table	By empirical equation	
°C										
30	11·84	58·9	58·4	58·6	58·6	57·57	59·04	−3·2	−0·5	−0·1370
30	14·13	66·1	65·4	65·5	65·7	64·92	66·40	−2·6	−0·2	−0·0586
30	16·43	73·9	73·1	73·2	73·4	72·78	74·41	−2·2	0·1	0·0024
30	46·39	188·3	186·7	187·4	187·5	189·3	189·0	−0·4	−0·5	0·3875
30	106·9	432·2	428·7	430·5	430·5	434·4	434·7	−0·5	−0·3	—
50	7·100	44·8	44·3	44·4	44·5	43·83	45·05	−2·9	−0·1	−0·3515
50	8·140	47·8	47·1	47·2	47·4	46·70	48·05	−2·9	0·1	−0·2938
50	17·30	76·6	75·9	75·9	76·1	75·92	77·30	−1·6	0·3	0·0259
50	21·43	91·2	90·5	90·5	90·7	91·10	91·93	−1·0	0·1	0·1125
50	34·83	142·5	141·5	141·2	141·7	143·5	143·2	−0·1	−0·2	0·2798
50	78·04	316·6	312·5	312·5	313·9	318·3	318·3	0	0·1	—
50	114·6	463·8	458·0	457·9	459·9	467·6	467·4	0·3	0·3	—
°F										
200	2·987	33·75	33·3	33·45	33·5	33·69	34·22	−0·8	0·8	—
200	4·621	38·3	37·8	38·0	38·0	37·94	38·54	−1·6	0·1	—
200	7·630	46·4	45·9	46·2	46·2	45·92	46·86	−2·0	0·1	—
200	16·20	73·5	72·8	72·7	73·0	73·10	74·01	−1·3	0·1	—
200	14·86	68·6	68·2	68·6	68·5	68·43	69·44	−1·5	0·1	—
200	22·72	97·1	96·7	96·6	96·8	97·44	97·30	−0·7	−0·8	—
200	34·23	142·3	141·0	140·6	141·3	143·6	141·7	0·2	−1·0	—
200	56·49	232·6	231·7	232·4	232·2	236·0	232·0	0·2	−1·4	—
						Standard deviation (%) =		1·69	0·52	

The values of ν/R are calculated from the values of pair of ν and R extracted from the above four bibliographical references, and the averages of A in the viscosity range greater than 70 cS were also determined, as shown in Table V. Since in the research data of Nagano and Oguma, the measured values at the kinematic viscosities greater than 70 cS at 200° F are not given, only the values of A at the temperatures of 30° and 50° C are set out in Table V.

The values of log log $\{A/(A-\nu/R)\}$ were calculated from the respective values of ν/R and A determined above, and were also plotted against log ν in Fig 1. For the purpose of comparison, identical calculations

were performed using the values taken from the Ubbelohde conversion table [6] corresponding to 70° F, and the result is shown as a straight line 1 in Fig 1.

It will be noted from Fig 1 that all of the points obtained from the Redwood viscometers (except viscometer No. 1307) and the points calculated by Iwanami,

TABLE V

Investigator	Viscometer	A
Barr (1936)	No. 1307	0·2462 (at 70° F)
Garner (1936)	No. 3967	0·2440 (at 70° F) 0·2416 (at 140° F)
Nagano (1955)	No. 4656 No. 1A No. 5385	0·2483 (at 30° C) 0·2489 (at 50° C)
Kinoshita (1955)	No. 5122 No. 5187 No. 5224 No. 5225	0·2482 (at 30° C) 0·2474 (at 50° C) 0·2463 (at 80° C) 0·2456 (at 100° C)
Iwanami (1955)	Calculated value	0·246 (at 70° F)

together with the points previously given by the author, lie quite close to the straight line 2. The straight line 2 can be represented by equation (3), in which the values of k and n are as follows :

$$\left.\begin{aligned} \log k &= -1{\cdot}1760 \\ k &= 0{\cdot}06668 \\ n &= 0{\cdot}9704 \end{aligned}\right\} \quad . \quad . \quad . \quad (7)$$

In accordance with IP 70/53, the measurement of the Redwood viscosity is widely based upon the Redwood seconds obtainable in the standard viscometer No. 1307 in the viscosity range of about 300–400 Redwood sec (about 70–100 cS) at room temperature, as a primary standard. It is estimated from the data of Barr's experiments [2] that the values of A at 70° F in the viscometer No. 1307 is 0·2462, as shown in Table V. The value of A at 70° F calculated by equation (6) is 0·2485. Hence, equation (6) was corrected by multiplying 0·2485/0·2462, or 1·0093, and the following equation is given

$$1/A = 1{\cdot}0093\,(4{\cdot}011 + 0{\cdot}00061t)$$

$$i.e.\ 1/A = 4{\cdot}048 + 0{\cdot}00062t \quad . \quad . \quad . \quad (8)$$

By substituting the values in (7) and (8) in equation (1), we have an empirical equation

$$R = (4{\cdot}048 + 0{\cdot}00062t)\nu/(1 - 10^{-0{\cdot}06668\,\nu^{-0{\cdot}9704}}) \quad . \quad (9)$$

which the author set out to derive.

CRITICISM OF THE UBBELOHDE CONVERSION TABLE

In order to criticize the Ubbelohde conversion table, the experimentally and theoretically determined Redwood seconds were compared with the Redwood viscosities converted from the kinematic viscosities by means of the conversion table, using the data obtained by various investigators previously quoted, as well as by the author.

The experimental kinematic viscosity in Table I was converted to the equivalent Redwood seconds by means of the above table and the relative deviation δ, as a percentage, of the converted Redwood seconds from the average experimental Redwood value was calculated by the following equation

$$\delta = 100 \times (R' - R)/R - b. \quad . \quad (10)$$

where R' = Redwood seconds converted from kinematic viscosity by means of the conversion table;

R = the experimentally determined Redwood seconds;

b = a correcting constant which will make the value of δ equal to zero in the viscosity range greater than 70 cS at low temperature.

The values of δ in Table I, calculated by taking 0·8 as the value of b in equation (10), are plotted against ν in Fig 2. The data of Garner, Nagano, and Iwanami, as previously quoted, were treated similarly and the values of δ were also plotted in Fig 2.

It is obvious from Fig 2 that a definite deviation develops in the viscosity range below approximately 30 cS (about 120 Redwood sec) in all cases and has a maximum amounting to as much as 3 per cent or more at a limited range of about 6–12 cS (about 40–60 Redwood sec). Although there is no remarkable deviation in the viscosity range greater than 30 cS, the author has found in his experiments that as the temperature increases the degree of deviation increases in the viscosity range beyond about 70 cS and the deviation reaches as high as 2 per cent at 100° C, as shown in Fig 2.

On the other hand, if the deviation of the converted Redwood seconds from the experimental Redwood values obtained by Barr with viscometer No. 1307 is similarly determined, it is found that, with the exception of the deviation of 2·1 per cent at the viscosity of 2·007 cS, the maximum deviation is 1·1 per cent at 30·05 cS and 0·52 per cent in terms of standard deviation. Furthermore, no characteristic deviation such as shown in Fig 2 can be found in the overall viscosity range.

Consequently, it has been recognized that Ubbelohde's conversion table possibly represents the relation between kinematic viscosities and Redwood seconds obtainable in the standard Redwood viscometer No. 1307 with the deviation of about 0·5 per cent. However, the table does not represent with certainty the relation between kinematic viscosities and Redwood seconds, which has not only been obtained experimentally in other Redwood viscometers, such as No. 3967 and other commercial instruments, but also calculated theoretically.

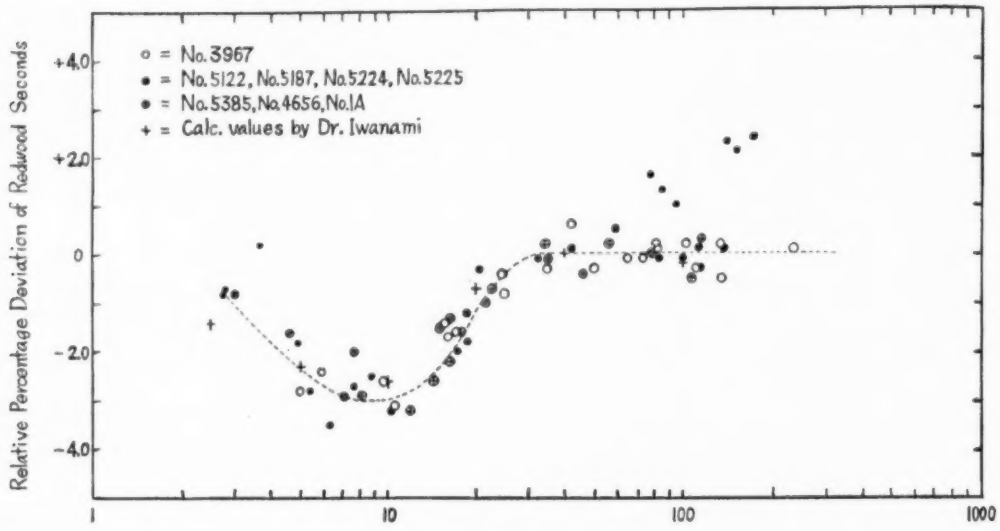

FIG 2

RELATIVE DEVIATION OF REDWOOD SECONDS OBTAINED BY MEANS OF THE UBBELOHDE CONVERSION TABLE FROM REDWOOD SECONDS

Obtained experimentally

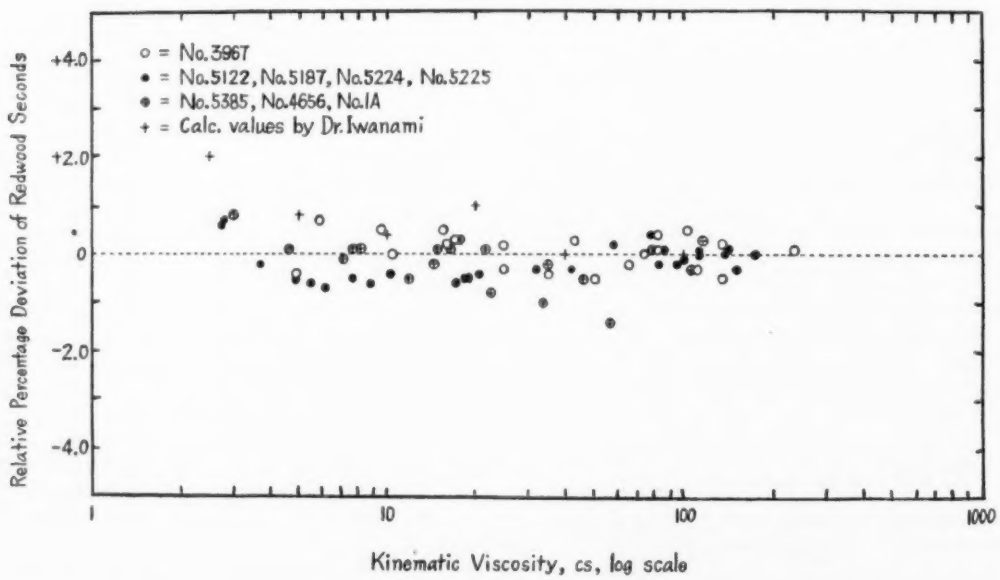

FIG 3

RELATIVE DEVIATION OF REDWOOD SECONDS OBTAINED BY MEANS OF NEW EMPIRICAL EQUATION FROM REDWOOD SECONDS

Obtained experimentally

It is obvious in Fig 1 that straight line 1, representing Ubbelohde's conversion table, passes satisfactorily near to all the experimental points of the viscometer No. 1307. (This straight line 1 in Fig 1 is drawn from equation (2) in which $A = 0{\cdot}2462$, $k = 0{\cdot}06838$, and $n = 0{\cdot}9864$. The Redwood seconds calculated by equation (2) taking these values deviate from the corresponding Redwood values of the conversion table at a maximum 0·6 per cent at the viscosity of about 31 cS and the deviation is 0·28 per cent in terms of standard deviation.) The measured values in other viscometers and calculated values of Iwanami are,

TABLE VI

Relative Percentage Deviation of Converted from Experimental Values in Terms of Standard Deviation

Investigator	Viscometer	Ubbelohde conversion table	Empirical equation
Barr (1936)	No. 1307	0·52	1·69
Garner (1936)	No. 3967	1·40	0·37
Kinoshita (1955)	No. 5122 No. 5187 No. 5224 No. 5225	1·73	0·41
Nagano (1955)	No. 4656 No. 1A No. 5385	1·69	0·52

however, represented by the straight line 2 in Fig 1. As previously explained, the difference between the above two straight lines in Fig 1 is believed to be due to differences in character of the viscometers themselves and not to correction factors of the viscometers. Therefore, it can be deduced from the above that the standard Redwood viscometer No. 1307 has some difference in character compared with the other viscometers, such as No. 3967, or other commercial viscometers. Consequently, it is also deduced that Ubbelohde's conversion table would indicate a characteristic deviation, as shown in Fig 2, when applied to other general Redwood viscometers.

If the kinematic viscosities in Table I are converted to Redwood seconds by means of the empirical equation (9) in place of Ubbelohde's conversion table, and the relative deviations δ of these values are determined from the experimentally-determined Redwood values by the identical methods indicated above, the results as shown in Table I are obtained. Fig 3 shows these relative deviations plotted against kinematic viscosities. Similarly, by using equation (9), the data of Garner, Nagano, and Iwanami were considered, and the relative deviations are also plotted in Fig 3. It is obvious from Fig 3 that there are no anomalous deviation characteristics, as is found in Fig 2, throughout the entire viscosity range greater than 3 cS. However, it is assumed that there would be a remarkable deviation in the viscosity range below about 2·5 cS (approximately 32 Redwood sec).

TABLE VII

New Conversion Table for Kinematic Viscosity to Redwood No. I Viscosity

Kinematic viscosity, cS	Equivalent Redwood No. I viscosity, sec								Kinematic viscosity, cS	Equivalent Redwood No. I viscosity, sec							
	20° C	70° F	30° C	50° C	140° F	80° C	200° F	100° C		20° C	70° F	30° C	50° C	140° F	80° C	200° F	100° C
3·0	33·9	33·9	33·9	34·0	34·1	34·2	34·2	34·3	36	147·2	147·2	147·4	147·8	148·1	148·5	148·8	148·9
3·5	35·2	35·2	35·2	35·3	35·4	35·5	35·5	35·6	37	151·2	151·2	151·4	151·9	152·1	152·5	152·8	153·0
4·0	36·5	36·5	36·5	36·6	36·7	36·8	36·9	36·9	38	155·2	155·2	155·4	155·9	156·1	156·6	156·9	157·0
4·5	37·8	37·8	37·8	38·0	38·0	38·1	38·2	38·2	39	159·1	159·1	159·3	159·8	160·0	160·5	160·8	161·0
5·0	39·1	39·1	39·2	39·3	39·4	39·5	39·5	39·6	40	163·1	163·1	163·3	163·8	164·1	164·6	164·9	165·0
5·5	40·5	40·5	40·5	40·7	40·7	40·8	40·9	41·0	41	167·1	167·1	167·3	167·8	168·1	168·6	168·9	169·1
6·0	41·8	41·8	41·9	42·0	42·1	42·2	42·3	42·3	42	171·1	171·1	171·3	171·9	172·1	172·6	172·9	173·1
6·5	43·2	43·2	43·3	43·4	43·5	43·6	43·7	43·7	43	175·2	175·2	175·4	176·0	176·2	176·8	177·1	177·2
7·0	44·6	44·6	44·7	44·8	44·9	45·0	45·1	45·1	44	179·2	179·2	179·4	180·0	180·3	180·8	181·1	181·3
7·5	46·0	46·0	46·1	46·2	46·3	46·4	46·5	46·6	45	183·2	183·2	183·4	184·0	184·3	184·8	185·2	185·4
8·0	47·4	47·4	47·5	47·7	47·7	47·9	48·0	48·0	46	187·2	187·2	187·4	188·0	188·3	188·9	189·2	189·4
8·5	48·9	48·9	48·9	49·1	49·2	49·3	49·4	49·5	47	191·2	191·2	191·4	192·0	192·3	192·9	193·3	193·5
9·0	50·3	50·3	50·4	50·5	50·6	50·8	50·9	50·9	48	195·2	195·2	195·4	196·1	196·4	196·9	197·3	197·5
9·5	51·8	51·8	51·9	52·1	52·1	52·3	52·4	52·4	49	199·3	199·3	199·5	200·2	200·5	201·1	201·5	201·7
10	53·3	53·3	53·4	53·6	53·6	53·8	53·9	54·0	50	203·3	203·3	203·5	204·2	204·5	205·1	205·5	205·7
11	56·4	56·4	56·5	56·6	56·7	56·9	57·0	57·1	51	207·3	207·3	207·5	208·2	208·5	209·1	209·5	209·7
12	59·5	59·5	59·5	59·7	59·9	60·1	60·2	60·2	52	211·4	211·4	211·7	212·3	212·6	213·2	213·7	213·9
13	62·6	62·7	62·7	62·9	63·0	63·2	63·3	63·4	53	215·4	215·4	215·7	216·3	216·7	217·3	217·7	217·9
14	65·9	65·9	66·0	66·2	66·3	66·5	66·6	66·7	54	219·5	219·5	219·8	220·5	220·8	221·5	221·9	222·1
15	69·2	69·2	69·3	69·5	69·6	69·8	69·9	70·0	55	223·5	223·5	223·8	224·5	224·8	225·5	225·9	226·1
16	72·5	72·5	72·6	72·9	73·0	73·2	73·3	73·4	56	227·5	227·5	227·8	228·5	228·8	229·5	230·0	230·2
17	75·9	75·9	76·0	76·3	76·4	76·6	76·8	76·8	57	231·6	231·6	231·9	232·6	233·0	233·7	234·1	234·3
18	79·4	79·4	79·5	79·8	79·9	80·1	80·3	80·3	58	235·7	235·7	236·0	236·7	237·1	237·8	238·2	238·5
19	82·9	82·9	83·0	83·3	83·4	83·6	83·8	83·9	59	239·7	239·7	240·0	240·8	241·1	241·8	242·3	242·5
20	86·4	86·4	86·5	86·8	86·9	87·2	87·4	87·5	60	243·8	243·8	244·1	244·9	245·2	246·0	246·4	246·7
21	90·0	90·1	90·2	90·5	90·6	90·9	91·0	91·1	61	247·9	247·9	248·2	249·0	249·3	250·1	250·6	250·8
22	93·6	93·7	93·8	94·1	94·2	94·5	94·7	94·8	62	251·8	251·9	252·2	253·0	253·4	254·1	254·6	254·9
23	97·3	97·3	97·5	97·8	97·9	98·2	98·4	98·5	63	255·8	255·9	256·2	257·0	257·4	258·2	258·7	258·9
24	101·0	101·0	101·1	101·5	101·6	101·9	102·1	102·2	64	259·9	260·0	260·3	261·1	261·5	262·3	262 8	263·1
25	104·7	104·7	104·8	105·2	105·3	105·6	105·8	105·9	65	263·9	264·0	264·3	265·2	265·6	266·3	266·9	267·1
26	108·5	108·5	108·6	109·0	109·1	109·5	109·7	109·8	66	268·0	268·1	268·4	269·3	269·7	270·5	271·0	271·3
27	112·3	112·3	112·4	112·8	113·0	113·3	113·5	113·6	67	272·0	272·1	272·4	273·3	273·7	274·5	275·0	275·3
28	116·1	116·1	116·2	116·6	116·8	117·1	117·4	117·5	68	276·1	276·2	276·5	277·4	277·8	278·7	279·2	279·5
29	119·9	119·9	120·0	120·4	120·6	121·0	121·2	121·3	69	280·1	280·2	280·6	281·5	281·9	282·8	283·3	283·6
30	123·7	123·7	123·8	124·2	124·4	124·8	125·0	125·2	70	284·2	284·3	284·7	285·5	286·0	286·9	287·4	287·7
31	127·6	127·6	127·8	128·2	128·4	128·7	129·0	129·1									
32	131·5	131·5	131·7	132·1	132·3	132·7	132·9	133·1									
33	135·5	135·5	135·7	136·1	136·3	136·7	137·0	137·1									
34	139·4	139·4	139·7	140·1	140·2	140·6	140·9	141·0									
35	143·3	143·3	143·5	143·9	144·1	144·6	144·8	145·0									
	Viscosities, over 70 cS multiply by									4·060	4·061	4·067	4·079	4·085	4·098	4·108	4·110

The experimental data of Barr, previously quoted, were also treated identically and the deviations of the calculated Redwood seconds by equation (9) from the measured values in the viscometer No. 1307 were determined. As the result of this calculation, it was found that, although the calculated Redwood seconds deviate from the measured values about 3 per cent in the viscosity range below about 10 cS, the deviation is 0·3 per cent at maximum in the viscosity range greater than about 35 cS, and beyond 70 cS (about 300 Redwood sec), the deviation is only 0·1 per cent.

To summarize the above results and for the purpose of comparing Ubbelohde's conversion table with the empirical equation (9), the relative deviations of Redwood seconds converted from the kinematic viscosities by means of both the Ubbelohde table and equation (9) from the measured values of Barr, Garner, Nagano, and the author are presented in terms of standard deviation, in Table VI. The deviation of Ubbelohde's table value for the viscometer No. 1307 is only 0·52 per cent, but for other viscometers the deviation is 1·4–1·7 per cent. On the other hand, the deviation of the empirical equation's value for the viscometer No. 1307 indicates 1·7 per cent, but for the other viscometers the deviation is about 0·5 per cent at maximum. It is therefore deduced that equation (9) may be applied to general Redwood No. I viscometers with a deviation of about 0·5 per cent in terms of standard deviation for the overall viscosity range above 3 cS. Furthermore, equation (9) satisfies the primary standard of Redwood seconds according to IP Standard Methods, as previously explained.

Therefore, the author, by using empirical equation (9), has prepared a new table to take the place of the Ubbelohde table for the conversion of kinematic viscosities to Redwood No. I seconds in the viscosity range above 3 cS at various temperatures, as shown in Table VII.

CONCLUSIONS

As the result of this investigation, the following conclusions have been drawn :

(1) The Ubbelohde conversion table, which is currently used for the conversion of kinematic viscosities to Redwood No. I seconds, possibly represents the relation between kinematic viscosities and Redwood seconds obtainable in the Redwood viscometer No. 1307, which has been adopted as a standard of reference by the Institute of Petroleum, with the deviation of about 0·5 per cent; however, the table does not represent with certainty the relation obtainable in other Redwood viscometers such as No. 3967 and other commercial instruments. The Redwood seconds obtained by conversion from kinematic viscosities by means of the above table show a characteristic deviation from the values observed in the general Redwood instruments at the range of about 30–120 Redwood sec (2–30 cS), and the deviation has a maximum amounting to as much as 3 per cent or more at a limited range of about 40–60 sec (6–12 cS).

(2) It can be deduced from the data of Barr's experiments that the standard viscometer No. 1307 has some difference in characteristics compared with the No. 3967 instrument or other commercial Redwood viscometers.

(3) The following empirical equation, derived by the present author, is suitable for the conversion of kinematic viscosities to Redwood No. I seconds in the viscosity range greater than about 3 cS (about 34 Redwood sec) at the temperatures between 20° and 100° C approximately:

$$R = (4{\cdot}048 + 0{\cdot}00062t)\nu/(1 - 10^{-0{\cdot}06668\,\nu^{0{\cdot}9794}})$$

where R and ν are Redwood No. I seconds and kinematic viscosities in cS respectively and t is temperature, ° C. A new conversion table has been developed by the author from the above equation to take the place of the Ubbelohde conversion table for the conversion of kinematic viscosities to Redwood No. I seconds in the viscosity range above 3 cS at various temperatures between 20° and 100° C.

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THE RELATION BETWEEN SAYBOLT UNIVERSAL VISCOSITIES AND KINEMATIC VISCOSITIES *

By MASUMI KINOSHITA †

SUMMARY

This paper gives an account of research undertaken with the object of deriving an empirical formula for converting kinematic viscosities to Saybolt Universal viscosities, analysing the experimental data obtained in the seven conventional Saybolt and in the routine capillary viscometers. The experimental data were previously observed for the purpose of determining the correction factors of the above Saybolt instruments, and the results were reported in detail in 1953. The research work published by Headington and Geniesse in 1937 and the ASTM viscosity conversion table were also discussed here, together with the author's experimental results. As the result of this investigation, it was found that the following empirical equation, which is of the same type as the equation previously deduced by the author to express the relation between Redwood seconds and kinematic viscosities, is also suitable for the conversion of kinematic viscosities to Saybolt Universal viscosities in the whole viscosity range greater than about 2 cS (about 33 Saybolt Universal sec) at temperatures between approximately 70° and 300° F.

$$S = (4{\cdot}6050 + 0{\cdot}000297t)\nu/(1 - 10^{-0{\cdot}0744\nu^{0{\cdot}9538}})$$

where S and ν are Saybolt Universal viscosities in seconds and kinematic viscosities in cS respectively, and t is temperature, ° F.

INTRODUCTION

THE relation between Saybolt Universal viscosities and kinematic viscosities has been studied experimentally and theoretically by various investigators since Herschel in 1919 [1] first prepared an equation for the conversion of Saybolt Universal viscosities to kinematic viscosities. His equation was of the following type

$$\nu = AT - B/T \quad . \quad . \quad . \quad (1)$$

where T and ν are Saybolt Universal viscosities and kinematic viscosities respectively, and A and B are constants. It was found, however, by the ASTM Committee on Viscosity Standards in 1922 [2] that at least two equations of the above type were necessary to express the relation between Saybolt Universal viscosities and kinematic viscosities. In 1937 the ASTM Committee on Viscosity Standards prepared a viscosity conversion table by a graphical method, and not by any equations, on the basis of experimental work performed by Headington and Geniesse.[3] This conversion table is the basis of the ASTM viscosity conversion table,[4] which is widely used for the conversion of kinematic viscosities to Saybolt Universal viscosities, and is also the basis of the conversion tables developed by Ubbelohde [5] and Inaba [6] *et al.*

The author, however, found an adequate empirical formula of the following type for converting kinematic viscosities ν to Redwood seconds R at a temperature of t.

$$R = (a_0 + a_1 t)\nu/(1 - 10^{-k\nu^n}) \quad . \quad . \quad (2)$$

where a_0 and a_1 are constants, and k and n are constants independent of both temperature and correction factors of Redwood viscometers. The author therefore arranged research for the purpose of ascertaining whether the above equation (2) is capable of representing the relation between Saybolt viscosities S and kinematic viscosities ν, replacing R in the equation (2) by S.

The experimental data obtained in the seven conventional Saybolt Universal viscometers and in the routine capillary viscometers of suspended-level type were those previously observed for the purpose of determining the correction factors of these Saybolt instruments and the results, already published in detail in 1953,[7] were discussed. The ASTM viscosity conversion table [4] mentioned above was also employed to derive the empirical equation. The experimental data observed by Headington and Geniesse [3] were also discussed.

Since the primary standard of viscosity, *i.e.* the viscosity value of pure water at 20° C, was revised in July 1953, and the new value of 1·0038 cS [8] has been widely adopted in place of the old value of 1·0068 cS, the kinematic viscosities indicated in this report are all based upon the new value, and the kinematic viscosities extracted from other references were also corrected to the new values.

DERIVATION OF EMPIRICAL EQUATION

The experimental data obtained by the author [7] are set out in Table I, which includes the values of kinematic viscosities, average Saybolt Universal viscosities, and standard deviation of observed Saybolt values, together with the values of ν/S calculated from them. By plotting the values of ν/S in Table I against ν, a smooth curve can be drawn through them, which indicates that the value of ν/S increases

* MS received 26 June 1956.

† Shinagawa Oil Research Laboratory, Showa Oil Co., Tokyo, Japan.

gradually with increments in ν and finally approaches a constant value, A, in the viscosity range greater than about 70 cS (about 300 Saybolt Universal sec), which is similar to the finding obtained in the Redwood–kinematic viscosity studies.

TABLE I

Experimental Data and Deviation of Calculated from Experimental Saybolt Results

t (° F) Temperature	ν (cS) Experimental kinematic viscosities	S (sec) Experimental Saybolt Universal viscosities: Average	Standard deviation sec	Standard deviation %	S (sec) Calculated Saybolt viscosities by experimental equation	Percentage deviation of calculated from experimental values	ν/S	log log $\left[\frac{A}{A-\frac{\nu}{S}}\right]$
210	2·279	33·97	0·38	(1·1)	34·06	0·3	0·0671	−0·7851
210	3·844	39·18	0·39	(1·0)	39·01	−0·4	0·0981	−0·5726
210	5·580	44·71	0·40	(0·9)	44·56	−0·3	0·1248	−0·4179
210	7·201	49·94	0·45	(0·9)	49·92	0·0	0·1442	−0·3103
210	11·68	65·44	0·78	(1·2)	65·74	0·5	0·1785	−0·1040
210	20·38	99·75	1·32	(1·3)	100·3	0·6	0·2043	0·1381
100	9·587	57·87	0·50	(0·9)	57·75	−0·2	0·1657	−0·1934
100	25·28	121·0	1·36	(1·1)	120·6	−0·3	0·2089	0·1941
100	39·74	184·6	2·19	(1·2)	185·6	0·5	0·2153	—
100	60·05	280·2	4·20	(1·5)	279·6	−0·2	0·2143	—
100	126·7	594·1	14·1	(2·4)	589·9	−0·7	0·2133	—
100	295·2	1395·3	31·5	(2·3)	1374·3	−1·5	0·2116	—
			Standard deviation (%) =			0·62		

The following formula was therefore proposed to express the relation between Saybolt Universal viscosities S and kinematic viscosities ν.

$$S = \nu/\{A(1 - 10^{-k\nu^n})\} \quad . \quad . \quad . \quad (3)$$

where k and n are constants. This equation can be rewritten as a linear formula

$$\log\log\{A/(A - \nu/S)\} = \log k + n\log\nu \quad . \quad . \quad . \quad (4)$$

In other words, by plotting $\log\log\{A/(A - \nu/S)\}$ against $\log\nu$, there should be obtained a straight line from the above equation (4), from which the values of k and n can be ascertained.

As the result of detailed study, by analysing the values in Table I the values of A at 100° and 210° F were estimated as 0·2148 and 0·2133 respectively to make the deviation a minimum. The values of $\log\log\{A/(A - \nu/S)\}$ were calculated from these values of A and ν/S as shown in Table I, and these are plotted against $\log\nu$ in Fig 1, in which the standard deviations in $\log\log\{A/A - \nu/S)\}$, calculated from the standard deviations in the measured values S in Table I are also shown. It is obvious from Fig 1 that a linear relation clearly exists between $\log\log\{A/(A - \nu/S)\}$ and $\log\nu$, independent of both temperature and the correction factor of the Saybolt Universal viscometer. Consequently, the conclusion is that the two constants k and n, which represent the straight line in Fig 1, are independent of both temperature and the correction factor of the Saybolt Universal viscometer. On the other hand, it is also apparent that the constant A is not only a function of temperature, but also includes the correction factor of the Saybolt viscometer.

The values of constants of equation (4) were then calculated from the values in Table I to be $\log k = -1{\cdot}1277$, $k = 0{\cdot}07452$, and $n = 0{\cdot}9539$. By means of equation (3) and these values, the kinematic viscosities in Table I were converted to the Saybolt Universal viscosities as given in Table I. It is indicated that the deviation of these calculated values

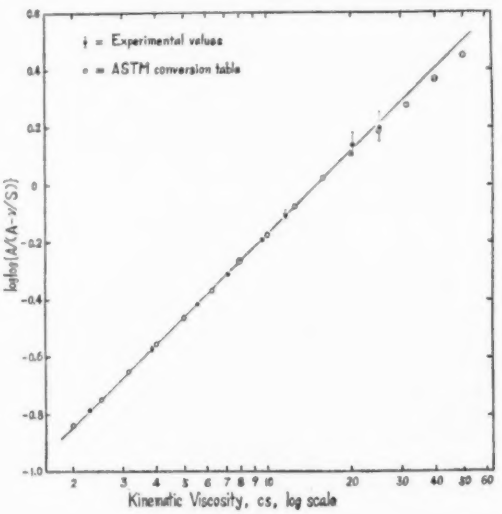

FIG 1

from the experimentally-determined Saybolt viscosities is 0·62 per cent in terms of standard deviation. If the experimental data for $\nu = 295{\cdot}2$ cS is omitted as anomalous, as previously reported, the deviation is at maximum 0·7 per cent and is only 0·42 per cent in terms of standard deviation.

Consequently, it can be recognized that the formula (3) is in fact suitable for expressing the relation between Saybolt Universal viscosities and kinematic viscosities. The author, therefore, with the object of establishing the equation (3) as a general formula, has determined the values of A, k, and n, taking all characteristics noted above and the ASTM viscosity conversion table [4] into consideration.

The values of pairs of ν and S at suitable viscosity intervals have been extracted from the ASTM viscosity conversion table [4] and set out in Table II, which also includes the values of ν/S calculated from them for the purpose of determining the values of A and $\log\log\{A/(A - \nu/S)\}$. The average values of A were determined from these values of ν/S in the viscosity range greater than 70 cS as 0·21575 and

0·21425, corresponding to 100° and 210° F respectively. By using these values of A and ν/S, the values of $\log \log \{A/(A - \nu/S)\}$ were calculated as shown in Table II, and also plotted against $\log \nu$ in Fig 1. It will be noted in Fig 1 that these points lie quite close to the same straight line as that previously given by the author, with the exception that beyond about 30 cS, in this viscosity range, the points from the conversion table deviate from this straight line. Nevertheless, the author believes, as is similarly found in the Redwood–kinematic viscosity relationships, that this deviation is due to the shortcoming of equation (3), as previously noted. Therefore, by omitting these deviated values, the constants of equation (4) corresponding to the straight line in Fig 1 were calculated from the values in Table II as follows:

$$\left.\begin{aligned} \log k &= -1{\cdot}1281 \\ k &= 0{\cdot}07445 \\ n &= 0{\cdot}9538 \end{aligned}\right\} \quad . \quad . \quad . \quad (5)$$

On the other hand, the ASTM viscosity conversion table [4] also includes the values of S/ν, or $1/A$, corresponding to various temperatures between −100° and 500° F in the viscosity range greater than 75 cS. As a result of analysis of these values, it is recognized that the values of $1/A$ have a linear relation to temperature t° F as shown by the following equation

$$1/A = 4{\cdot}6050 + 0{\cdot}000297t \quad . \quad . \quad (6)$$

By substituting the values in (5) and (6) in equation (3), the equation is

$$S = (4{\cdot}6050 + 0{\cdot}000297t)\nu/(1 - 10^{-0{\cdot}07445\nu^{0{\cdot}9538}}) \quad . \quad . \quad . \quad (7)$$

This is the empirical formula, which the author set out to derive.

DISCUSSION

The kinematic viscosities in Table II were converted to the equivalent Saybolt Universal viscosities by means of the empirical equation (7) and the deviation, as a percentage, of these values from the Saybolt viscosities converted by means of the ASTM conversion table was also determined as given in Table II. It is indicated that the deviation is at maximum 0·4 per cent, with the exception of 0·6 per cent at the viscosity of 2·0 cS, and is 0·23 per cent in terms of standard deviation.

The experimental data obtained by Headington and Geniesse [3] are extracted in Table III. The experi-

TABLE II

Deviation of Calculated from Saybolt Viscosities by Conversion of Kinematic by ASTM Conversion Table

ν (cS) Kinematic viscosities	S (sec) Saybolt Universal viscosities by conversion of kinematic				$100 \times \left(\frac{S_2 - S_1}{S_1}\right)$		$\log \log \left(\frac{A}{A - \frac{\nu}{S}}\right)$
	S_1 by ASTM conversion table		S_2 by new empirical equation *				
	100° F	210° F	100° F	210° F	100° F	210° F	
2·0	32·62	32·85	32·81	33·04	0·6	0·6	−0·8380
2·5	34·43	34·67	34·40	34·64	−0·1	−0·1	−0·7491
3·16	36·54	36·80	36·46	36·72	−0·2	−0·2	−0·6528
4·0	39·14	39·41	39·09	39·36	−0·1	−0·1	−0·5547
5·0	42·35	42·65	42·23	42·53	−0·3	−0·3	−0·4633
6·3	46·53	46·85	46·41	46·73	−0·3	−0·3	−0·3676
8·0	52·09	52·45	52·06	52·42	−0·1	−0·1	−0·2673
10·0	58·91	59·32	58·98	59·39	0·1	0·1	−0·1731
12·6	68·27	68·75	68·05	68·53	−0·3	−0·3	−0·0758
16·0	81·30	81·87	81·45	82·02	0·2	0·2	0·0238
20·0	97·77	98·45	97·63	98·31	−0·1	−0·1	0·1089
25·0	119·3	120·1	118·8	119·6	−0·4	−0·4	0·1882
31·6	148·4	149·4	147·9	148·9	−0·3	−0·3	0·2754
40·0	186·3	187·6	186·0	187·3	−0·2	−0·2	0·3649
50·0	232·1	233·8	231·9	233·5	−0·1	−0·1	0·4496
63·0	292·1	294·2	292·0	294·0	0·0	−0·1	0·5427
80·0	370·8	373·4	370·8	373·4	0	0	—
100·0	463·5	466·7	463·5	466·7	0	0	—
126·0	584·0	588·1	584·0	588·1	0	0	—
160·0	741·6	—	741·6	—	0	—	—
200·0	926·9	—	927·0	—	0	—	—
			Standard deviation (%) =		0·23	0·23	

* $S = (4{\cdot}6050 + 0{\cdot}000297 \, . \, t) \, . \, \nu/(1 - 10^{-0{\cdot}07445\nu^{0{\cdot}9538}})$.

TABLE III

Experimental Data by Headington and Geniesse

t (° F) Temperature	ν (cS) Experimental kinematic viscosities	S (sec)			Percentage deviation of converted from experimental values	
		Experimental Saybolt universal viscosity	Saybolt viscosities by conversion of kinematic			
			By ASTM conversion table	By new empirical equation *	By ASTM conversion table	By new empirical equation *
70	6·919	48·5	48·43	48·35	−0·1	−0·3
70	14·86	77·1	76·68	76·84	−0·5	−0·3
70	91·13	422·0	421·4	421·5	−0·1	−0·1
70	118·0	547·4	545·9	545·8	−0·3	−0·3
100	2·996	35·9	36·02	35·95	0·3	0·1
100	4·427	40·5	40·50	40·41	0·0	0·2
100	5·185	43·0	42·94	42·82	−0·1	−0·4
100	8·395	53·4	53·43	53·40	0·1	0·0
100	8·824	54·8	54·89	54·87	0·2	0·1
100	13·65	72·4	72·22	72·36	−0·3	−0·1
100	55·02	163·7	163·74	163·3	0·0	−0·2
100	58·19	177·6	178·10	177·7	0·3	0·0
100	45·17	209·3	209·7	209·7	0·2	0·2
100	63·29	293·1	293·4	293·4	0·1	0·1
100	99·60	460·4	461·5	461·6	0·2	0·3
100	259·4	1204·0	1202·0	1202·3	−0·2	−0·1
100	1326·0	6158·0	6145·0	6145·7	−0·2	−0·2
130	3·081	36·3	36·36	36·28	0·2	−0·1
130	5·344	43·4	43·53	43·40	0·3	0·0
130	19·28	94·7	94·74	94·83	0·0	0·1
130	21·45	103·8	104·05	103·9	0·2	0·1
210	1·914	32·5	32·51	32·76	0·0	(0·8)
210	2·283	34·0	33·84	33·95	−0·5	−0·1
210	2·999	36·3	36·33	36·21	0·1	−0·2
210	4·071	39·7	39·70	39·58	0·0	−0·3
210	5·633	44·7	44·68	44·56	−0·1	−0·3
210	5·773	45·1	45·13	45·02	0·1	−0·2
210	7·667	51·3	51·35	51·29	0·1	−0·0
210	13·22	71·4	71·09	71·23	−0·4	−0·2
210	19·99	98·4	98·41	98·27	0·0	−0·1
210	26·14	125·3	125·17	124·6	−0·1	−0·6
210	63·86	297·6	298·1	298·1	0·2	0·2
300	2·433	34·5	34·65	34·62	0·4	0·3
300	2·413	34·5	34·68	34·56	0·9	0·2
			Standard deviation (%) =		0·23	0·23

* $S = (4{\cdot}6050 + 0{\cdot}000297 \, . \, t) \, . \, \nu/(1 - 10^{-0{\cdot}07445\nu^{0{\cdot}9538}})$.

mentally-determined kinematic viscosities were similarly converted to the Saybolt Universal viscosities by means of both the ASTM conversion table and equation (7). The percentage deviation of the converted Saybolt viscosities from the experimentally-determined Saybolt values were also evaluated in a similar way, as set out in Table III. It is indicated in Table III that the deviation of the Saybolt viscosities converted by means of the equation from the experimental Saybolt values is at maximum 0·6 per cent, with the exception of 0·8 per cent at the viscosity of $\nu = 1{\cdot}914$ cS, and is 0·23 per cent in terms of standard deviation, while the deviation of Saybolt viscosities converted by means of the ASTM table from the experimental values is at maximum 0·5 per cent and 0·23 per cent in terms of standard deviation.

Consequently, it can be recognized that the empirical equation (7) is suitable as a general formula for the conversion of kinematic viscosities to Saybolt Universal viscosities in the whole viscosity range greater than about 2 cS (about 33 Saybolt Universal sec) at temperatures between 70° and 300° F approximately.

CONCLUSIONS

As the result of this investigation, it was found that the following empirical equation, which is of the same type as the equation previously derived by the author to express the relation between Redwood seconds and kinematic viscosities, is suitable for the conversion of kinematic viscosities to Saybolt Universal viscosities in the whole viscosity range greater than about 2 cS (about 33 Saybolt Universal sec) at temperatures between 70° and 300° F approximately.

$$S = (4{\cdot}6050 + 0{\cdot}000297t)\nu/(1 - 10^{-0{\cdot}07445\nu^{0{\cdot}9538}})$$

where S and ν are Saybolt Universal viscosities in seconds and kinematic viscosities in cS respectively, and t is temperature, ° F.

ACKNOWLEDGMENTS

The author wishes to express his deep gratitude to Naojiro Ishii, the director of the Shinagawa Research Laboratory, and to Akira Wakana, the department manager, for their guidance in the prosecution of this research work; and to Dr Yoshio Tanaka, honorary professor at Tokyo University, and Dr Yuzaburo Nagai, Director of the Institute of Science and Technology of Tokyo University, for their helpful suggestions. The author also wishes to thank Masuhiro Onoyama and Miss Tomiko Miwa for their co-operation, and the directors of the Showa Oil Co. for permission to publish this work.

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CORRESPONDENCE

DETECTION OF BENZENE VAPOUR

The Editor, *Journal of the Institute of Petroleum.*

SIR,

Methods for the Detection of Toxic Gases in Industry. Leaflet No. 4. Benzene Vapour (second edition, 1955). (Issued by the Department of Scientific and Industrial Research.)

An error has been found in the standardization of this test as published which necessitates alteration of the table of concentrations given on p. 5 of this booklet. The revised table reads as follows:

No. of inflations of aspirator bulb	Concentration of benzene (approx.)	
	P.p.m.	Mg/cm
1	120	400
2	60	200
3	40	130
4	30	100
5	24	80
6	20	65

An amended table is to be issued by H.M. Stationery Office, and copies will be circulated to all purchasers of the apparatus used in conjunction with this test.

It will be noted that the original table gave higher concentrations of benzene than those actually present, so that the error has tended to safety. It is felt, however, by my committee that this revision should be brought to the notice of all persons who might be interested in this test.

Yours faithfully,

J. NIXON,
Secretary, Committee for Tests for Toxic Substances in Air.

Ministry of Labour and National Service,
Factory Department,
Engineering and Chemical Branch,
19 *St James's Square,*
*London, S.W.*1,
25 *February* 1957.

CETANE NUMBERS—THEIR DETERMINATION AND SIGNIFICANCE

The Editor, *Journal of the Institute of Petroleum.*

SIR,

We note with interest the article "Cetane Numbers—Their Determination and Significance" in the February 1957 issue of the *Journal.* Whilst we welcome this article on work in which we have collaborated and agree that the statements are factually correct, there are two opinions towards the end which, in our opinion, are open to question and may convey wrong impressions to readers not closely associated with the work.

First, at the end of the penultimate paragraph, "the standard deviations . . . were usually slightly better in the German tests. This could be attributed to the greater diversity of engine types in British laboratories." This may be true. But it could, alternatively, be attributed to the greater diversity of the types of fuel tested in the British programme. This point seems to be worthy of consideration, although it is not clearly brought out in the article.

Secondly, at the beginning of the last paragraph, "It is unlikely that much better agreement can be achieved while so many engine types are in use. . . ." Within the IP scheme, there is a small batch of identical engines (the CFR–ASTM) while the rest of the engines are all different. All the engines have been operated on the same diversity of fuels. Is there any evidence from the results, over the last two years or so, that the standard deviation of the identical engines is better than that of the non-identical engines? If there is, the results should be published. If there is not, then the case for a standard engine falls down without any question of the precision obtainable being "adequate for routine commercial testing."

Yours faithfully,
R. TOURRET and R. W. BALE

Admiralty Oil Laboratory,
Brentford, Middlesex,
21 *February* 1957.

The Editor, *Journal of the Institute of Petroleum.*

SIR,

With reference to the second paragraph of the letter of 21 February from Messrs Tourret and Bale I would point out that the article states on p. 66 that the tests were made by British and German laboratories on nine fuel samples, and I would emphasize that these were identical in the two countries. There is, therefore, no question of a greater diversity of fuels in the British programme. Five of these samples were commercial type fuels, and the statement

regarding standard deviations can be supported by the following data :

Sample No.	Standard Deviation	
	German Laboratories	British Laboratories
138A	1·04 *	1·10
140	0·54 *	1·83
152	0·97	1·46
162	1·26	1·36
163	0·94	1·90

* Includes some tests using T.13 and U.6.

It seems that the opening sentence of the final paragraph was unintentionally ambiguous; the word "agreement" was used in the sense of agreement between average cetane numbers in the two countries. I feel that the comment is justified by the statement at the bottom of p. 66 that "the HWA engine tends to rate at least one cetane number higher than the BASF. Similar trends are observable between individual British engines . . ." The Panel has, on several occasions, weighed the arguments for and against standardizing a specific type of test engine, but is not yet in a position to make any recommendation to the Standardization Committee.

Yours faithfully,

K. ARTER

Chairman, Ignition Quality of Diesel Fuels Panel, IP Standardization Sub-Committee No. 5

Abingdon, Berkshire,
4 *March* 1957.

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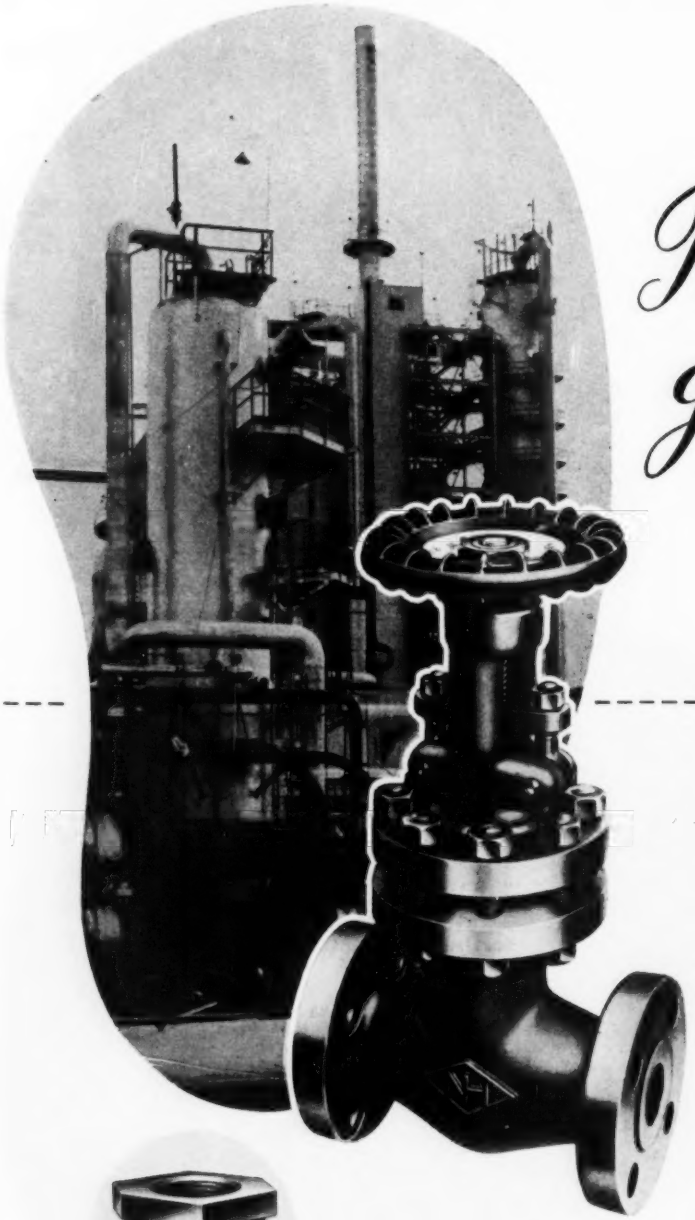

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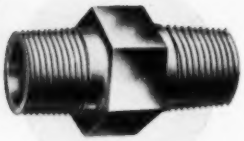

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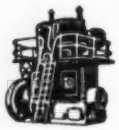

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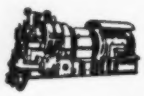

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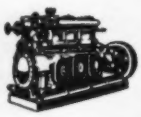

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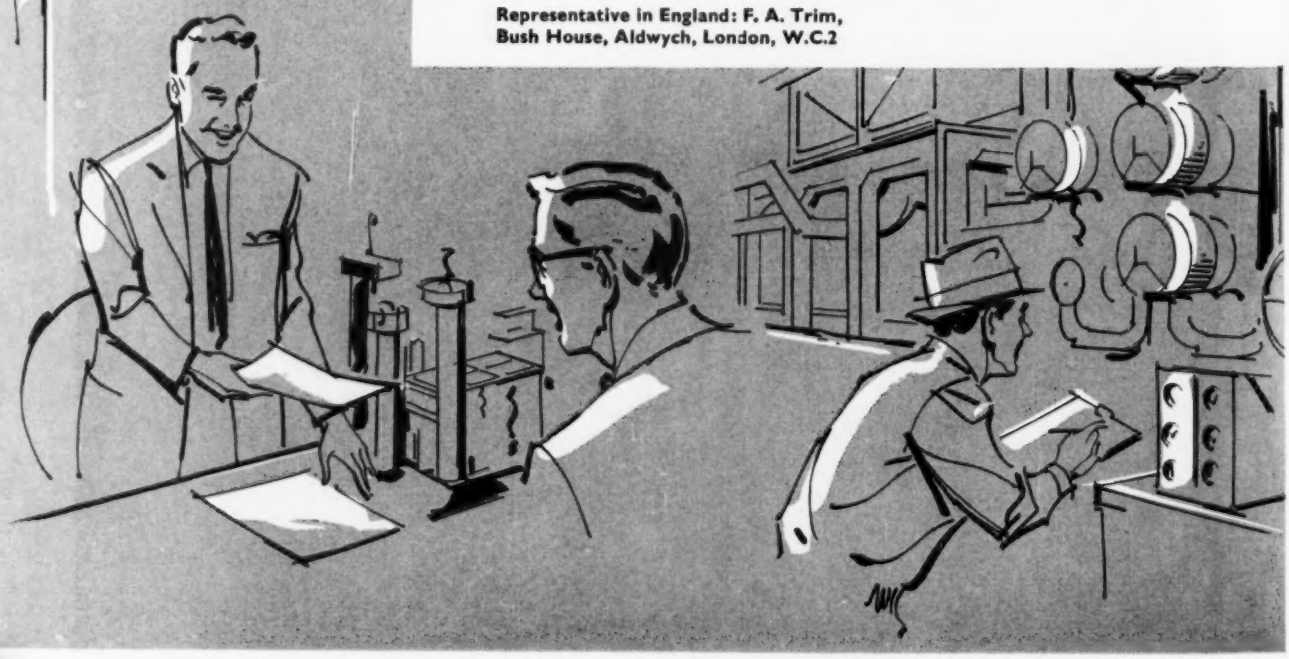

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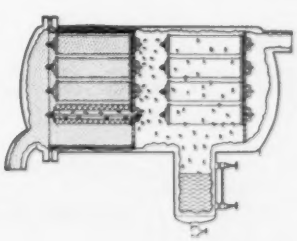

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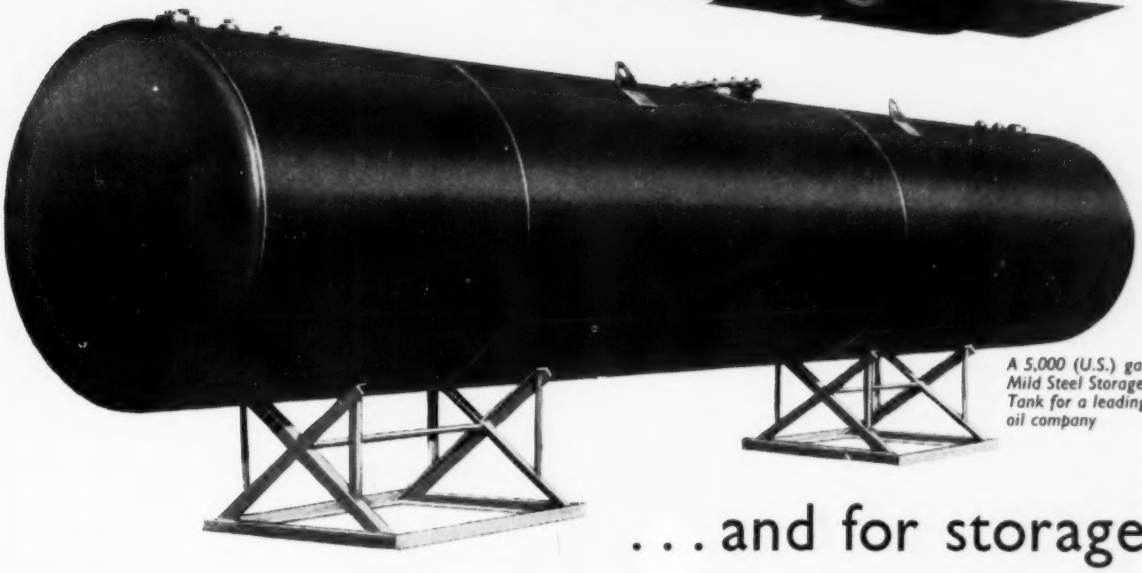

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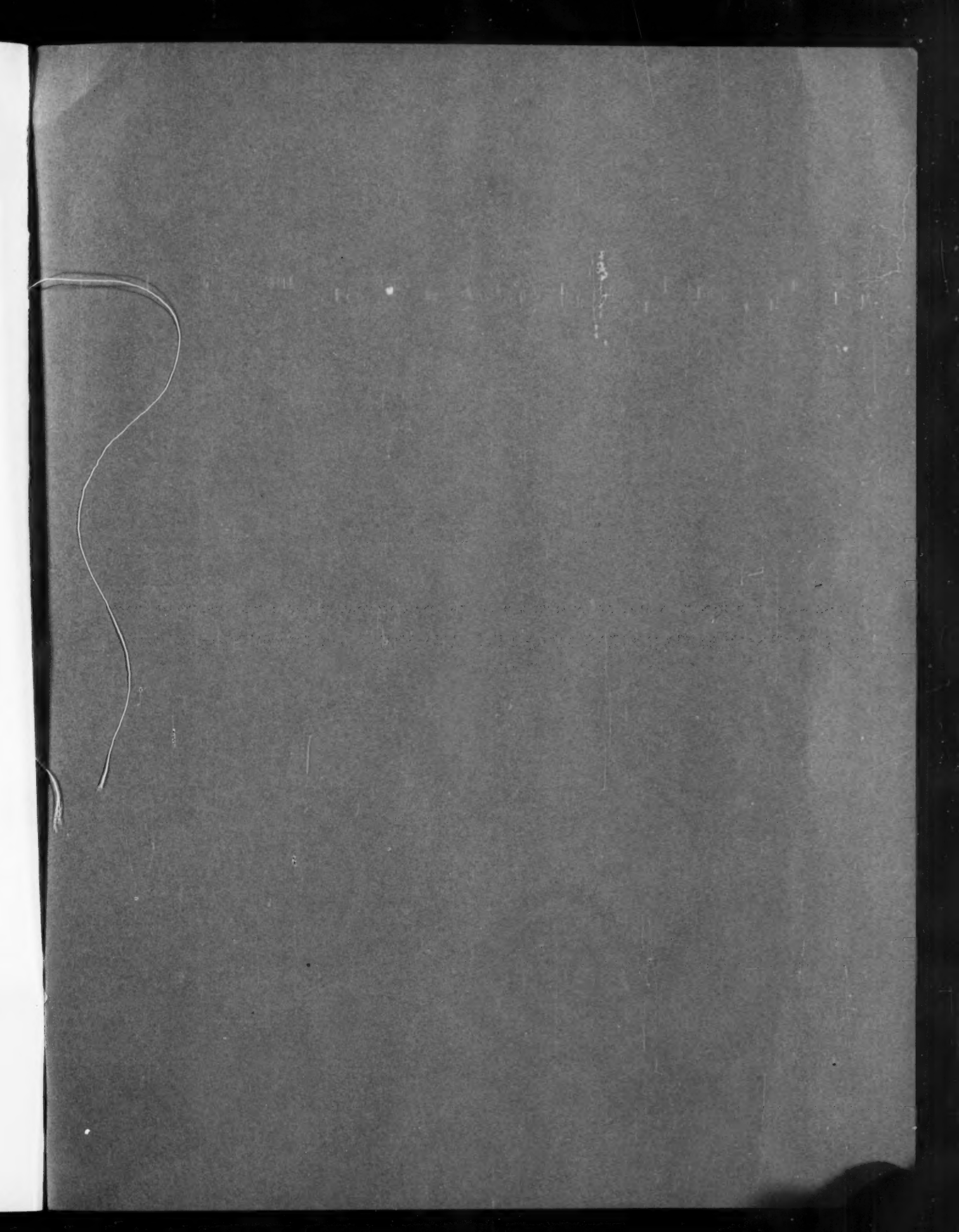

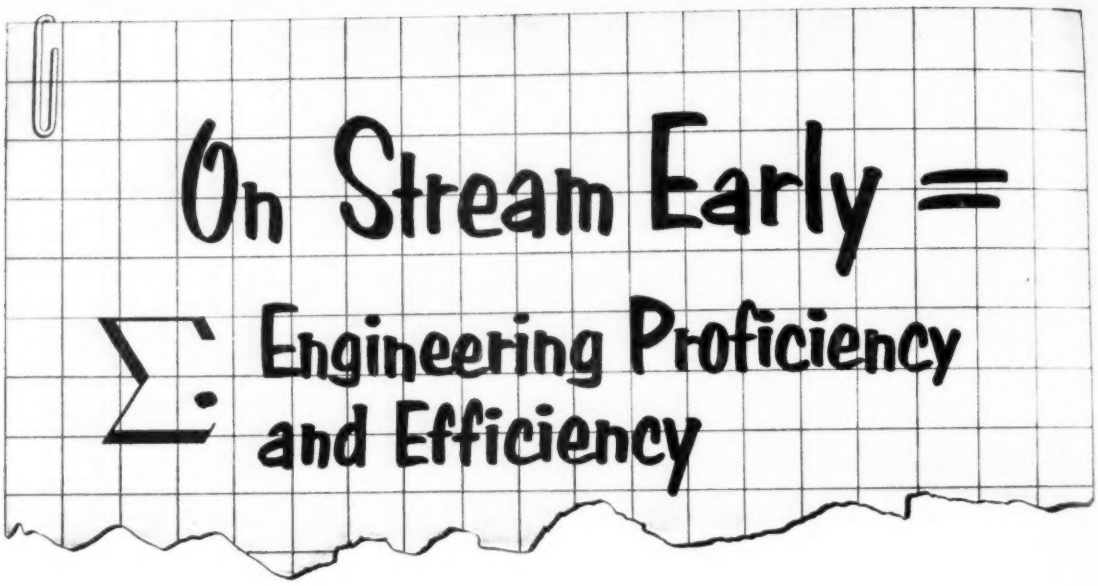

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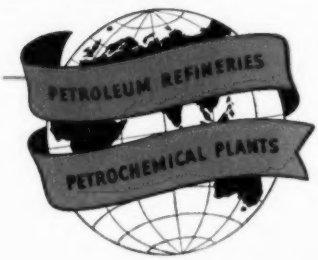

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